National Aeronautics and Space Administration

2017 Annual Report

NASA Small Business Innovation Research and Small Business Technology Transfer (SBIR/STTR)

SBIR·STTR
America's Seed Fund™
POWERED BY NASA

www.nasa.gov

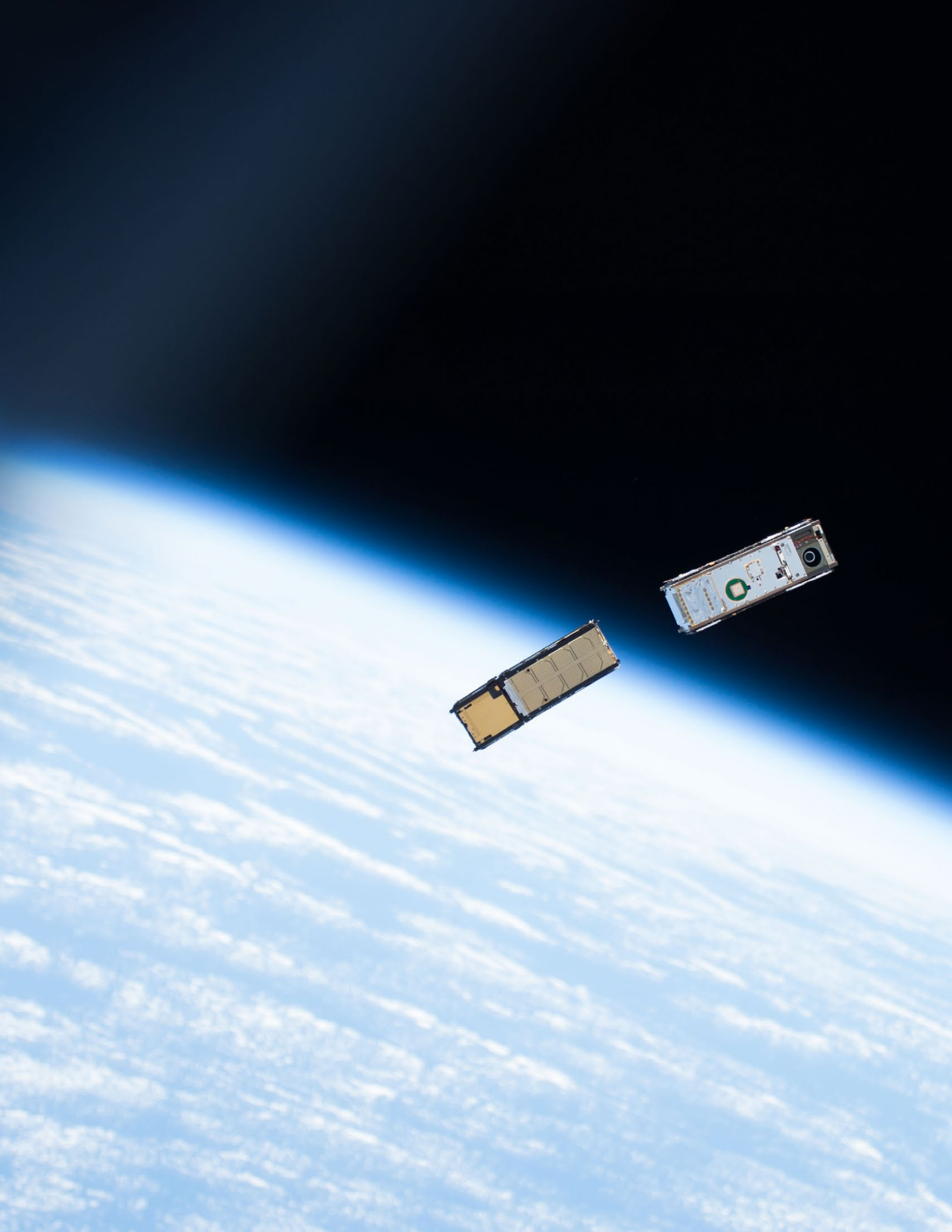
Mission

Create opportunities through SBIR/ STTR awards to leverage small business knowledge and technology development for maximum impact and contribution.

Vision

Empower small businesses to deliver technological innovation that contributes to NASA's missions, provides societal benefit, and grows the U.S. economy.

TABLE OF CONTENTS



INTRODUCTION

The National Aeronautics and Space Administration's (NASA) Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs leverage the nation's innovative small business community to support early stage research and development. These programs provide the small business sector with an opportunity to compete for funding to develop technology for NASA and to commercialize that technology to spur economic growth. NASA issues annual SBIR and STTR program solicitations, setting forth a substantial number of topic areas open to qualified small businesses. Specific research areas funded by the SBIR/STTR programs typically address the future mission needs of NASA's Mission Directorates – Science, Aeronautics Research, Human Exploration and Operations, and Space Technology. SBIR and STTR funding awards are divided into three phases.

This report is based on Phase I and Phase II awards made in FY2016. CCRPP is not included because it was not available in FY2016. Phase III is not included because it is funded from sources other than the SBIR/STTR program.

PHASE I

Provides the opportunity to establish the scientific, technical and commercial merit and feasibility of the proposed innovation in fulfillment of NASA needs.

Awards of up to $125,000.

Period of performance for SBIR is 6 months. STTR contracts last up to 12 months.

PHASE II

Focuses on the development, demonstration, and delivery of the proposed innovation. Includes only firms that have successfully completed Phase I.

Awards of up to $750,000.

Period of performance is 24 months.

Phase II-E encourages the advancement of innovations and awards up to $375,000 under a matching fund arrangement for a minimum of a 4-month extension.

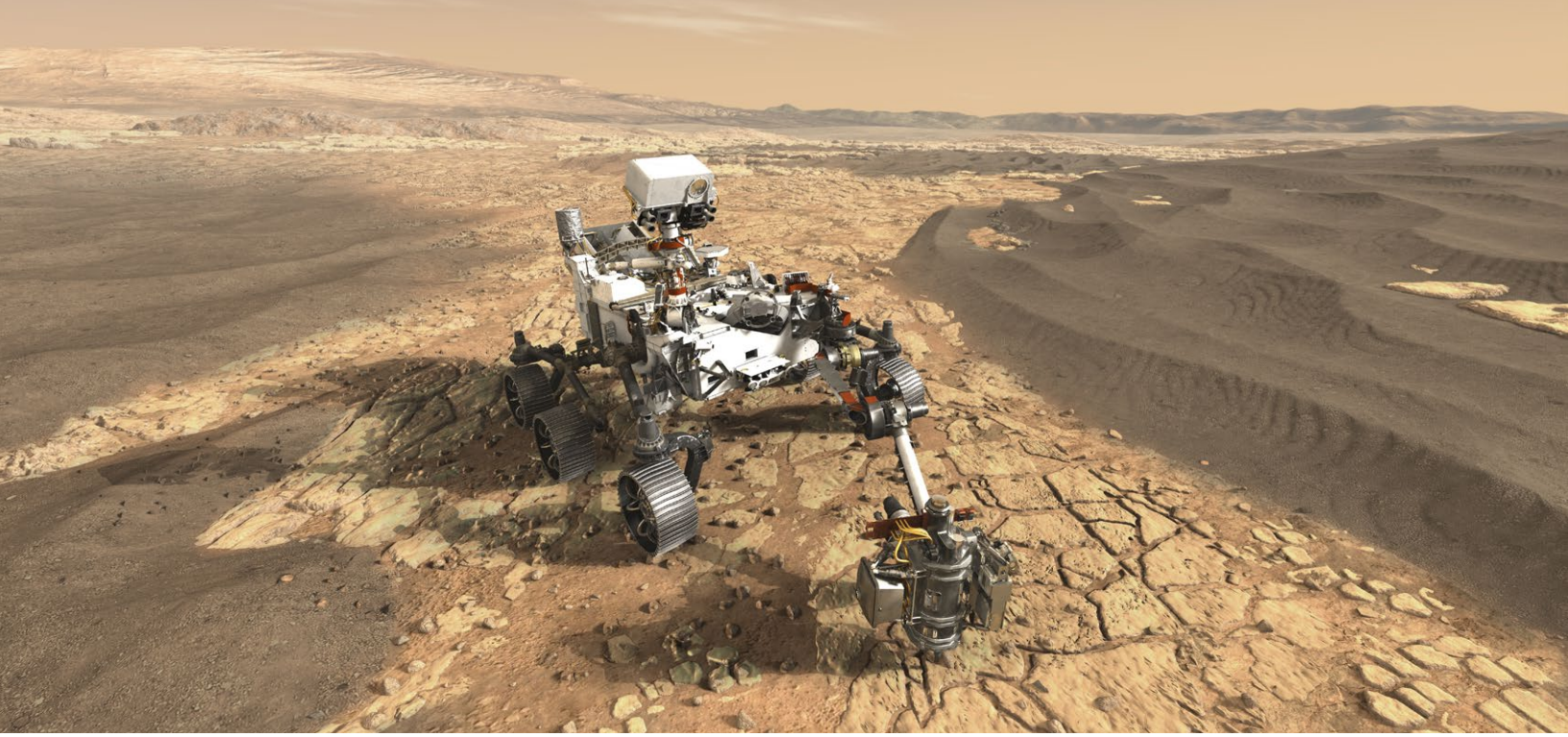
Civilian Commercialization Readiness Pilot Program (CCRPP) supports technology maturation that require more funds or time, awards up to $2M under a matching fund agreement for an extended period of roughly 24 months.

PHASE III

Moving innovative technologies, resulting from either a Phase I or Phase II contract, towards commercialization.

Funded from sources other than SBIR/STTR program and may be awarded with no further competition.

The primary difference between the STTR program and the SBIR program is that for STTR, small businesses must partner with a non-profit organization or a university.



FINANCIALS & AWARDS

NASA issues annual SBIR and STTR program solicitation with a substantial number of technology topic areas open to qualified small businesses. Both the list and description of topics are sufficiently comprehensive to provide a wide range of opportunities for small business concerns, research institutions, and universities to participate in NASA's research and development programs.

The annual reauthorization of the SBIR and STTR programs increases the required rate of investment for each program relative to extramural Agency Research and Development (R&D) beginning in FY2012 and continuing through FY2017. In accordance with the SBIR/STTR Reauthorization Act of 2011 (Public Law 112-81), NASA increased the SBIR investment by 0.20 percent to 3.2 percent of Agency extramural R&D for FY17. In addition, STTR funding remains at 0.45 percent of Agency extramural R&D. Historically, the percentage of Phase I proposals to awards is approximately 13-15% for SBIR and STTR, and approximately 35-40% of the selected Phase I contracts are competitively selected for Phase II follow-on efforts.

KEY STATISTICS BY PROGRAM - FY2016

Figure 1: SBIR Obligated Funding - $152.8 Million

The map illustrates participation level by state. In FY2016, CA received the most funding.

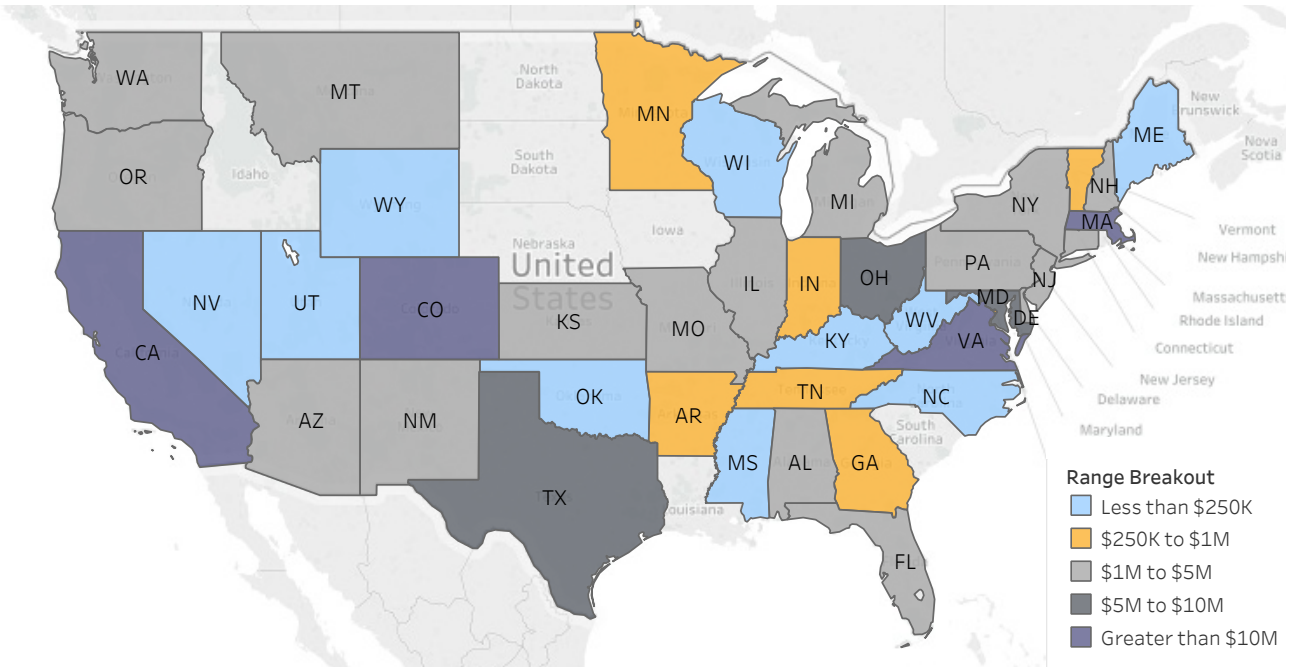


Figure 2: STTR Obligated Funding - $20.1 Million

The map illustrates participation level by state. In FY2016, CA received the most funding.

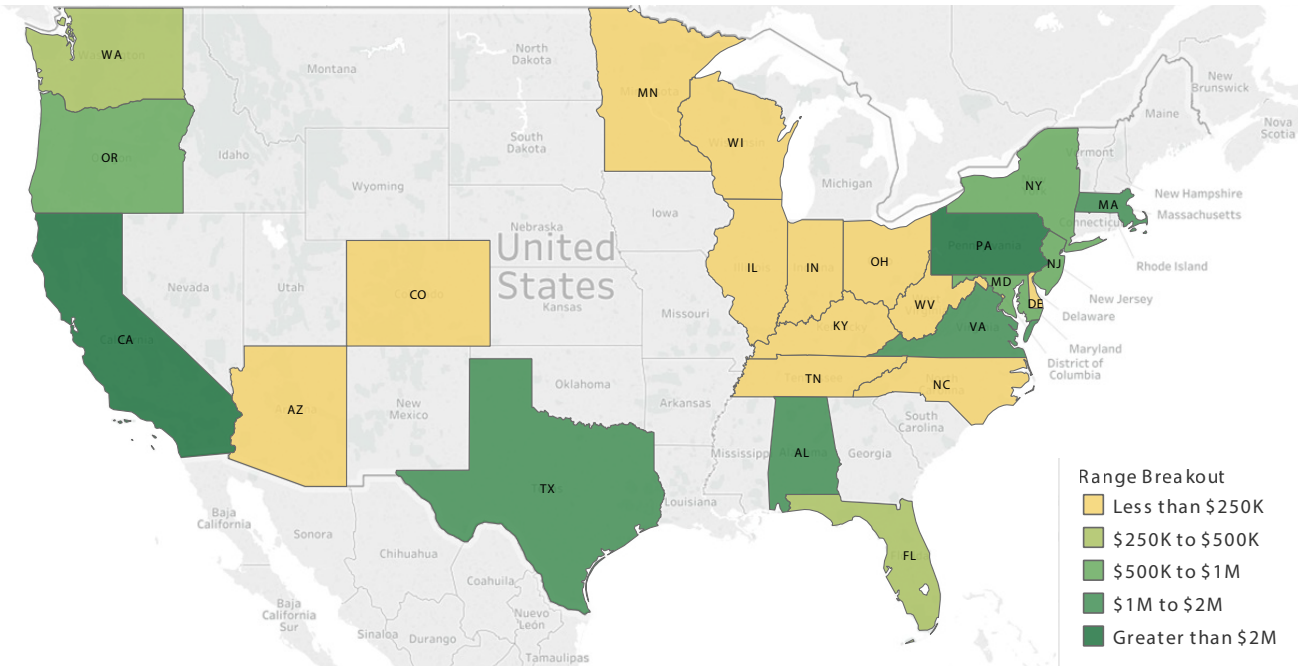


Figure 3: SBIR Investment by Mission Directorate

The Science Mission Directorate and Human Exploration and Operations Mission Directorate received the most investment from the SBIR program in FY2016. For a detailed breakout of investment by mission directorate and technology areas, see page 24.

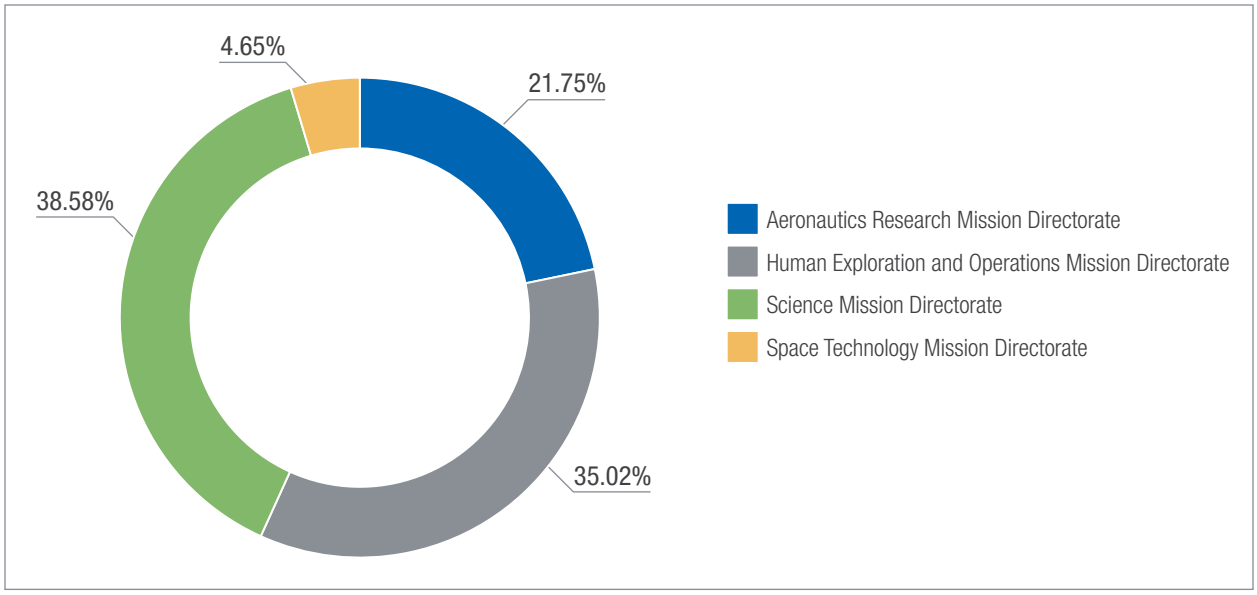


Figure 4: SBIR Award Distribution by Center

The Langley and Glenn Research Centers received the highest number of awards from the SBIR program in FY2016.

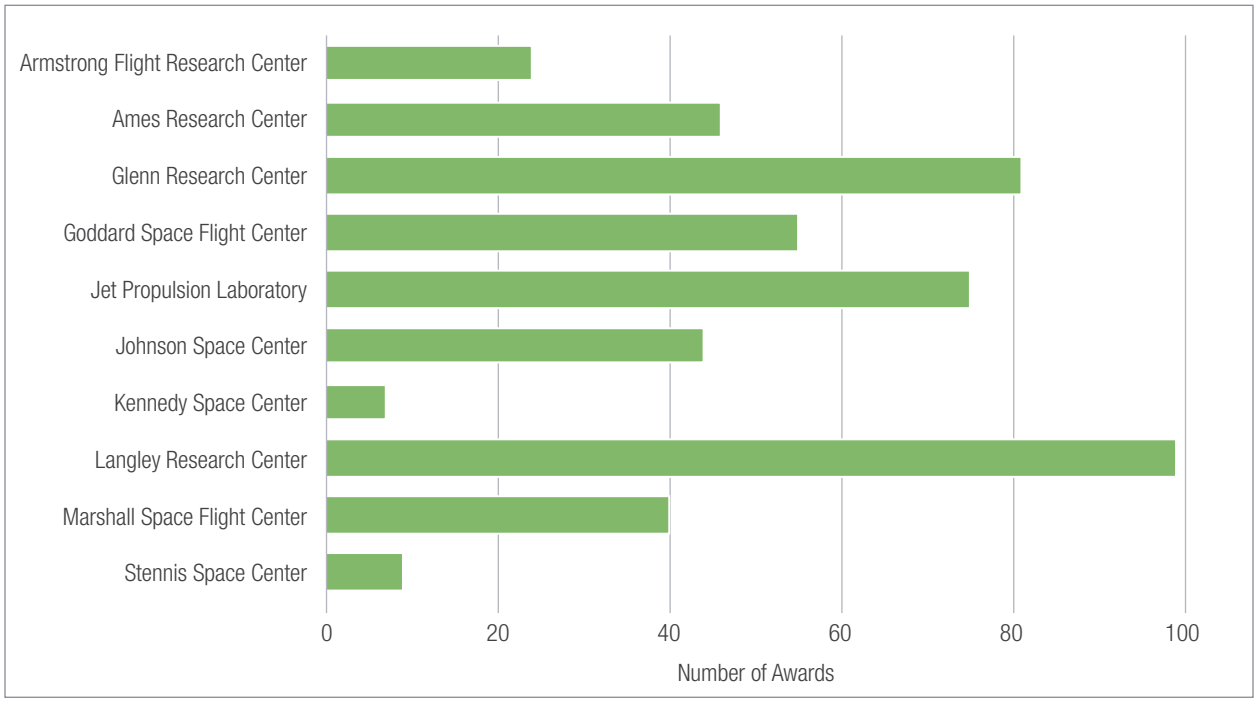


Figure 5: STTR Award Distribution by Center

The Langley and Ames Research Centers received the highest number of awards from the STTR program in FY2016.

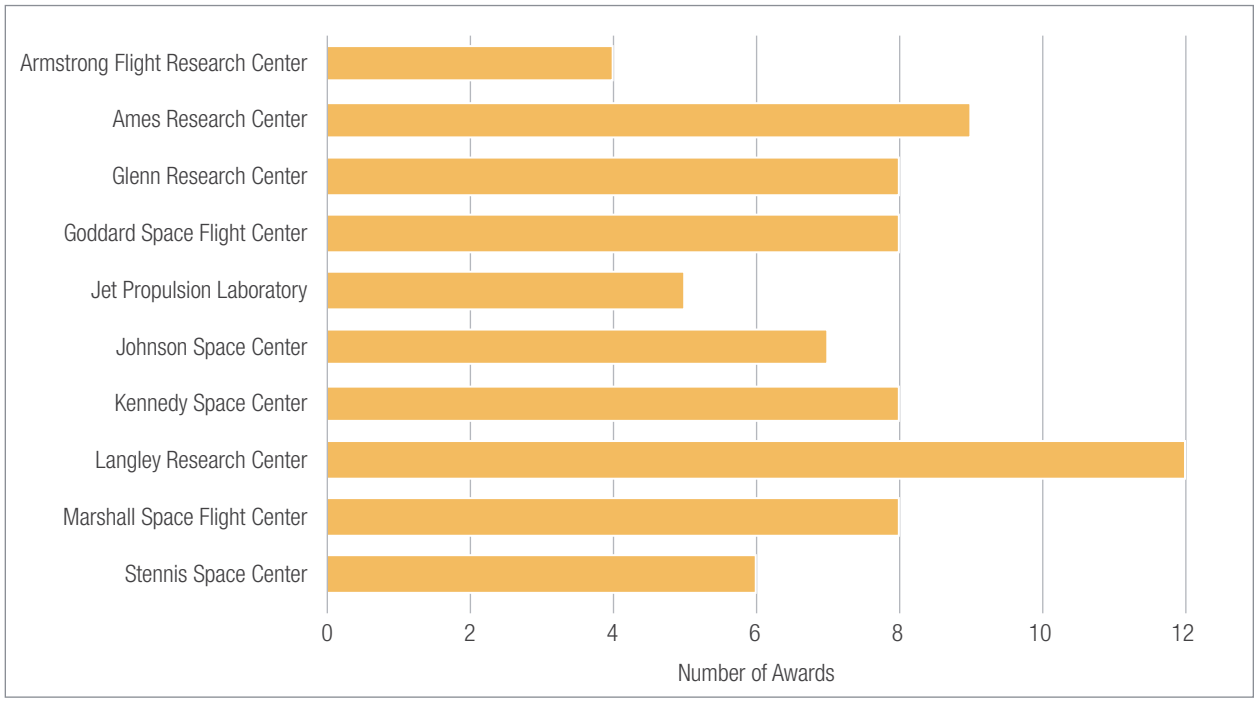


Figure 6: Firm Size by Program

The majority of participating Firms had fewer than 50 employees.

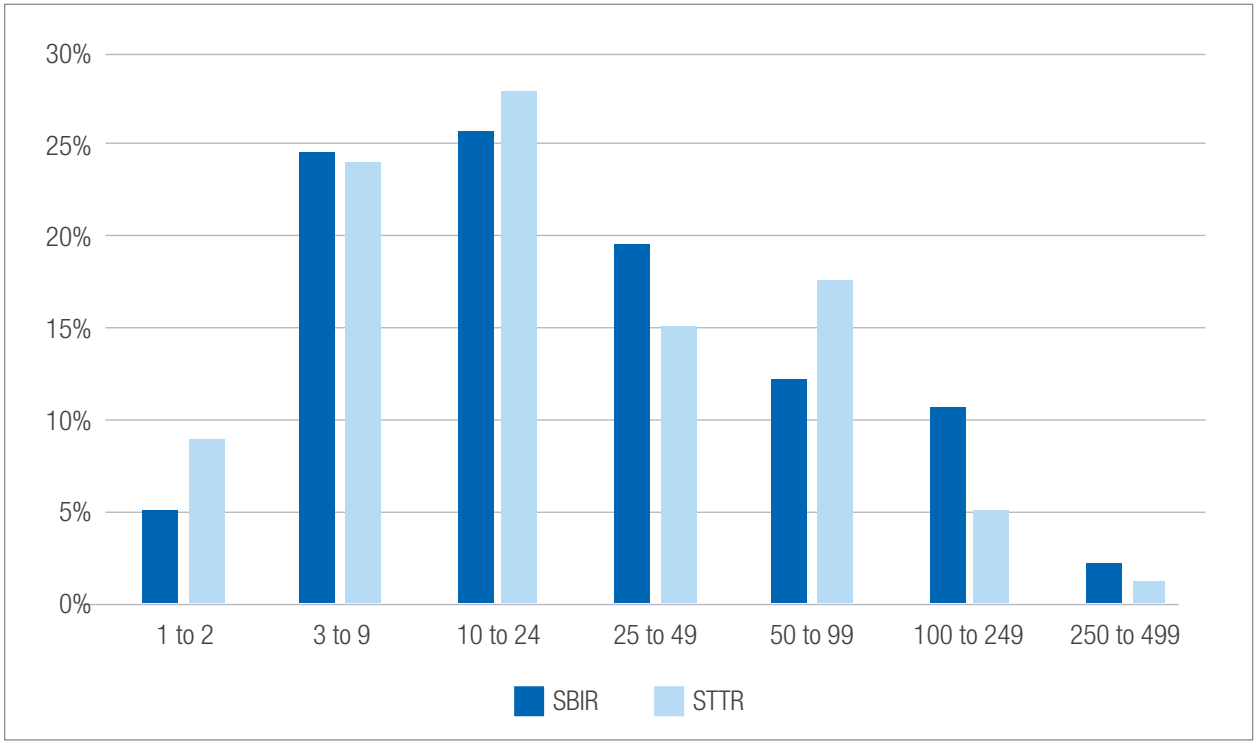
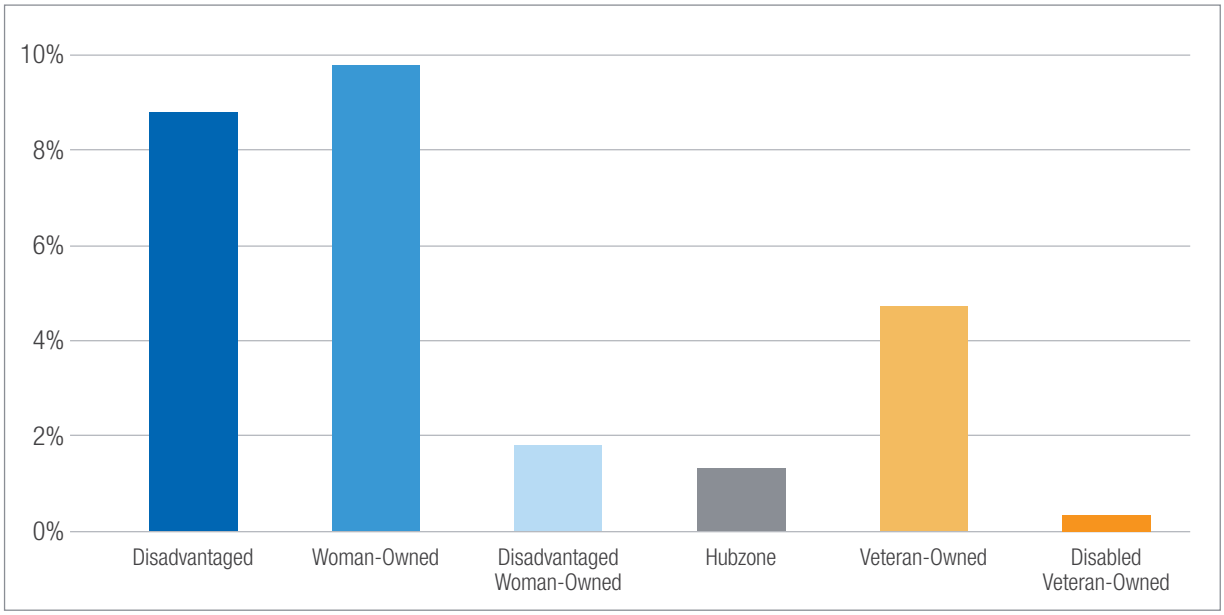


Figure 7: SBIR Firm Ownership*

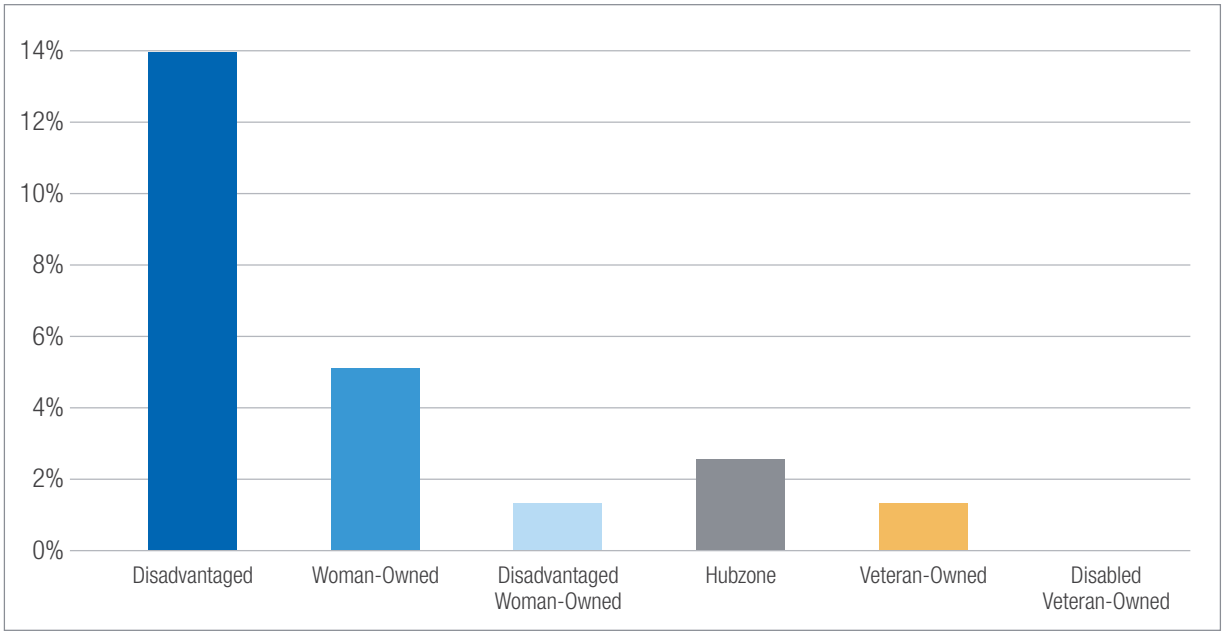
Nearly 12% of awards went to women-owned firms.



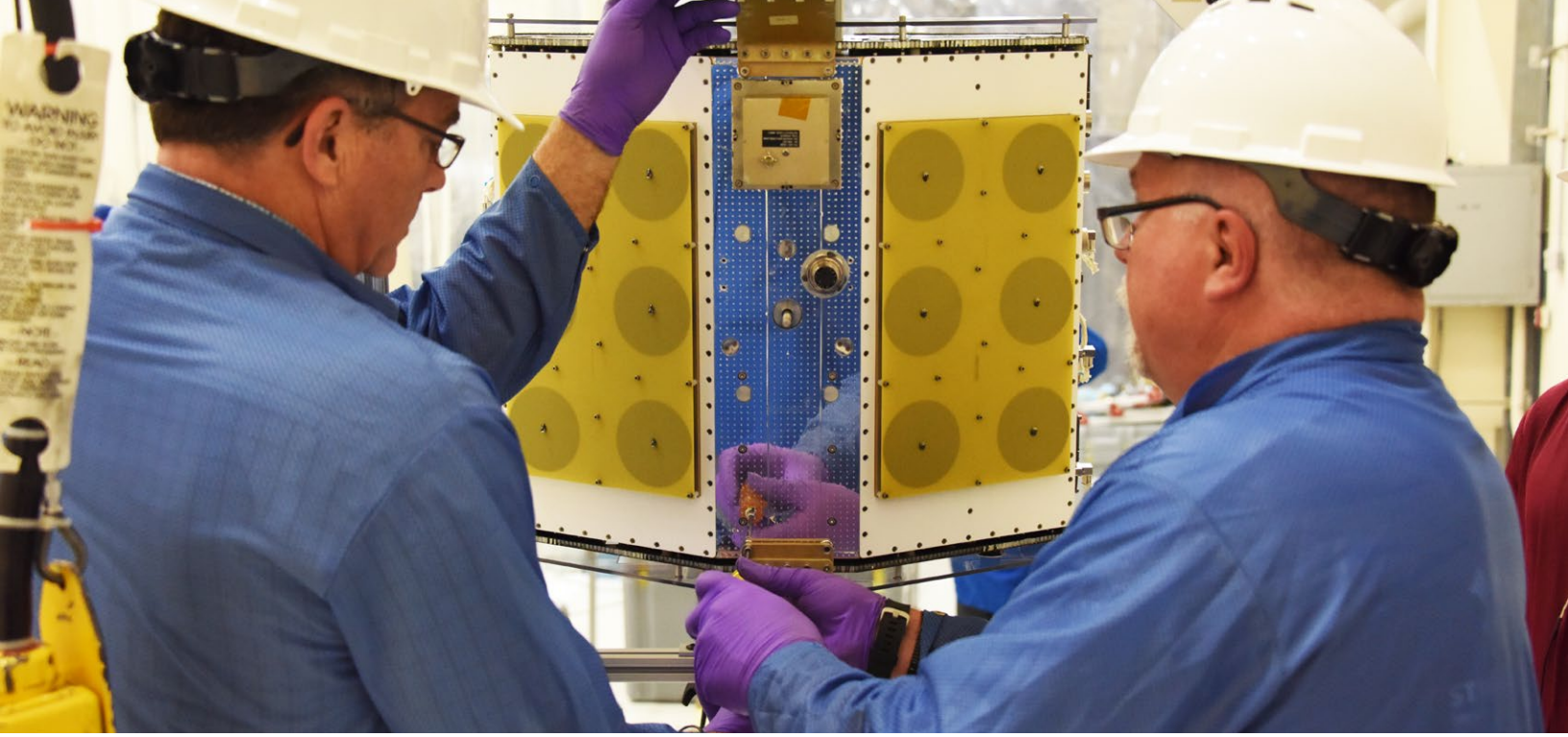
*As reported during proposal submission

Figure 8: STTR Firm Ownership*

Nearly 7% of awards went to women-owned firms.

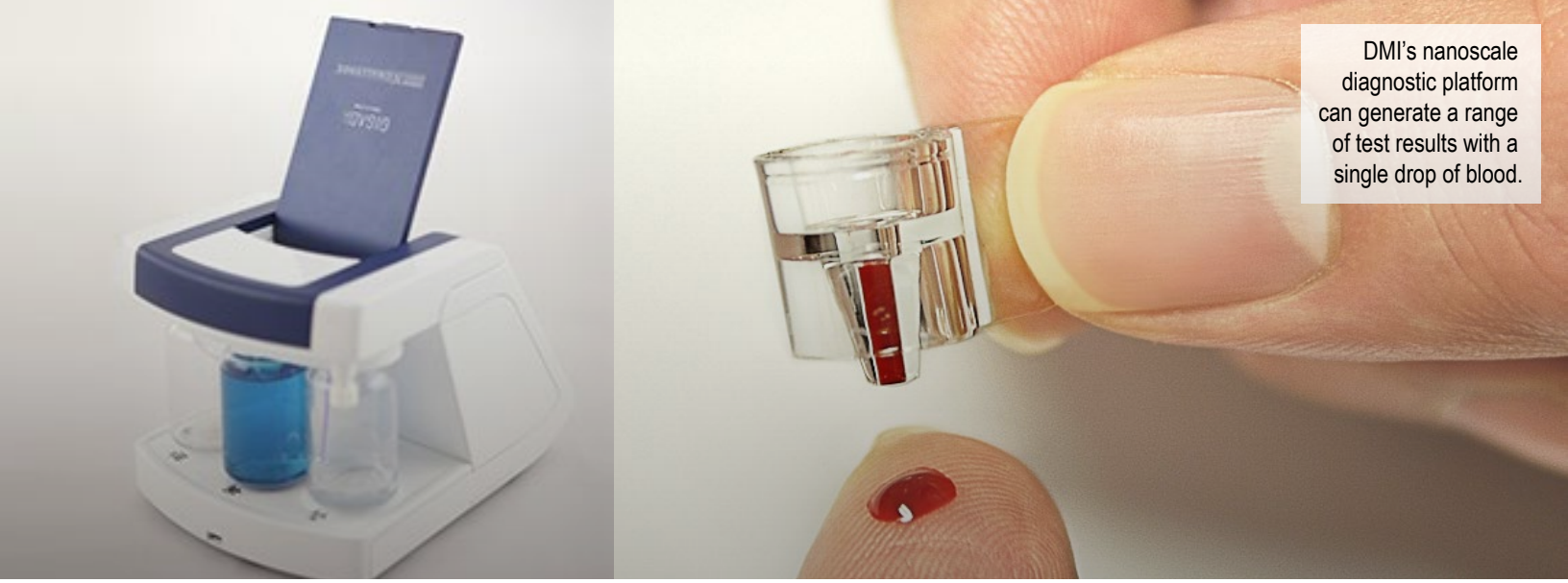


*As reported during proposal submission



HIGHLIGHTED SUCCESS STORIES

Success stories capture technology innovations spanning several years, involving multiple industries and dual use technologies with commercial and space applications. A success story also captures the challenging task of transitioning and commercializing the firm's technology from an idea into the market. The following pages highlight just a few of the many success stories of small businesses that have created new approaches and solutions resulting in improved capabilities not only for NASA but also for commercial markets. Additional success stories can be found on www.sbir.nasa.gov/success-stories.



DMI's nanoscale diagnostic platform can generate a range of test results with a single drop of blood.

DNA MEDICINE INSTITUTE

Getting timely medical attention while traveling in outer space has its complications. Astronauts encounter delayed communications from mission control due to the incredibly long distance from Earth. This could increase health risks if a medical consultation is needed. What if astronauts could conduct their own health check during a mission to Mars and administer treatment right on the spacecraft?

Project
Easy and non-intrusive nanoscale diagnostic platform comprised of fluorescence-based test strips and a hand-held sensor.

Mission Directorate
Science

Phase III Success
$525,000 Grand Prize winner of the Nokia XChallenge. Over several million dollars in funding from private investors, and multiple biotech and pharmaceutical partners.

Snapshot
Self-diagnosis for astronauts on long missions in outer space is possible using an innovative blood analysis system which can generate comprehensive medical test results within minutes using a single drop of blood.

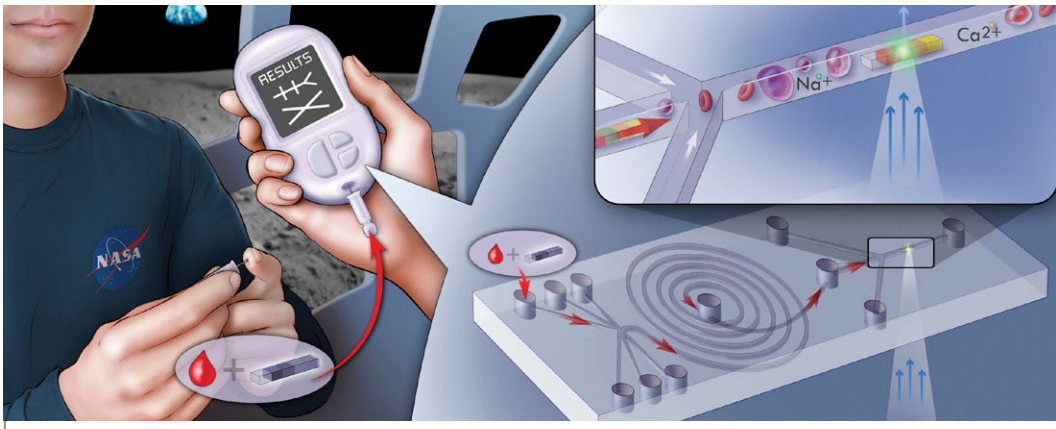
DNA Medicine Institute
727 Massachusetts Ave
Cambridge, MA 02139
dnamedinstitute.com

DNA Medicine Institute (DMI), through NASA's Small Business Innovation Research (SBIR) program, is making self-diagnosis in outer space a reality and revolutionizing the overall approach to medical testing. NASA had been searching for ways to monitor the health of astronauts during long missions using tests that would be easy to administer and are not intrusive. NASA also wanted to enable astronauts to address medical issues immediately without waiting for guidance from mission control. DMI, a med-tech incubator, laboratory, and biomedical technology service provider based in Cambridge, MA, developed a comprehensive nanoscale diagnostic platform to meet these stringent requirements.

DMI's solution includes fluorescence-based test strips, a hand-held sensor and software to generate a medical results dashboard. This innovative blood analysis system is easy to use. An astronaut simply applies one drop of blood to a small receptacle where reagents and the test strips react to the blood's contents. Using DMI's single point of care device, referred to as Reusable Handheld Electrolytes & Lab Technology for Humans (rHEALTH), the astronaut scans the test strips like a bar code in the receptacle to detect a whole host of disease-markers. The test strips are conceptually similar to pH or urinalysis test strips. However, the design allows for multiple, simultaneous measurements.

"Our system requires fewer samples to generate a comprehensive set of results and saves time by reducing the number of tests conducted. With the same test, astronauts can conduct a bone loss diagnosis, an immune system assessment, and rapid diagnosis of cardiac events within minutes," according to Dr. Eugene Chan, DMI Chief Executive Officer and Head Scientist.

DMI's test strips, the size of 165 by 33 micrometers, are produced to handle a microliter (tiny drop) of blood. To get an idea of the scale of the strip, the width of a single human hair ranges from approximately 10 to 200 micrometers. The nanostrips each have the mass and volume at the nano range, occupying no more than the volume of a few blood cells.



Two different lasers are used to detect the test strip and the targets in the blood sample to generate a comprehensive health profile.

A benefit of the test strip's small size is that it reduces the need for bulky lab equipment. The nanoscale diagnostic platform is designed to make conducting traditional medical tests, currently performed on large machines with trained personnel, possible without a lab by consumers or clinicians in resource challenged settings.

Encoded with fluorescent tags, the test strips incorporate several sensor pads that emit light in response to different proteins in the blood sample. The target in question will glow if it's in the sample and its fluorescent intensity indicates how much is present. The rHEALTH sensor uses two different lasers to detect the fluorescence, or light emissions. One laser identifies the test strip and the other measures the target on the test strip. The data gathered from the sensor is then rapidly analyzed to generate a comprehensive report on the patient's overall health.

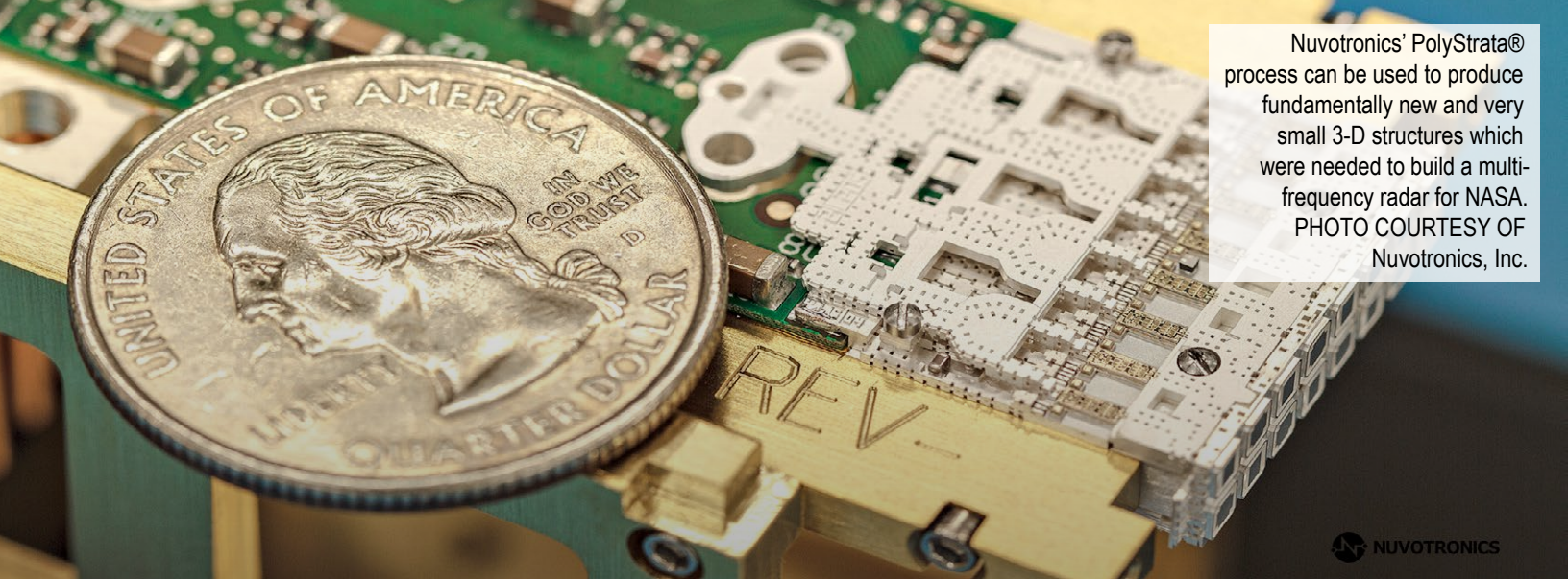
> "SBIR provided DMI with the opportunity to help astronauts understand their medical status on space flights. Now, we are working to make that same system available to the everyday consumer using readily available technology."
>
> **DMI**
> Founder
> DR. EUGENE CHAN

The rHEALTH sensor was designed to perform flawlessly in a zero gravity, low humidity and high radiation environment, while at the same time preserving the integrity of the biological fluids during testing. DMI determined the viability of the rHEALTh sensor in outer space by conducting reduced-gravity experiments for NASA's Facilitated Access to the Space Environment for Technology (FAST) program. FAST provides opportunities for emerging technologies to be tested in the space environment. A joint team from DMI and NASA's Glenn Research Center flew the device aboard a Boeing 727 at repeated parabolic trajectories to test the device functionality at zero, lunar, and 1.8 g conditions with promising results.

The rHEALTH sensor earned DMI the distinction of being the 2014 winner of the Nokia XChallenge, a $2.25 million global competition which aims to accelerate innovation and availability of hardware sensors and software sensing. DMI was also one of five finalists in the Qualcomm Tricorder XPRIZE, a $10 million global competition aimed to stimulate innovation and integration of precision diagnostic technologies to help consumers make their own reliable health diagnoses.

DMI is now making inroads to provide real-time health monitoring for patients on Earth. DMI is performing preliminary testing of its rHEALTH devices to determine blood cell counts and levels of immune markers. This consumer testing, as part of SBIR Phase III, is funded from DMI's XPRIZE award, private investors, and multiple biotech and pharmaceutical partners which amounts to over several million dollars of investment. DMI is almost half-way through the device development process for Federal Drug Administration approval.

From Left to Right: Samuel Bearg - SMI Special Projects Scientist, Dr. Eugene Chan - DMI CEO/Founder, Carlos Barrientos - DMI Graphic Designer/Media Specialist



Nuvotronics' PolyStrata® process can be used to produce fundamentally new and very small 3-D structures which were needed to build a multi-frequency radar for NASA. PHOTO COURTESY OF Nuvotronics, Inc.

NUVOTRONICS INC.

Local news meteorologist typically comes to mind when we think of weather predictions rather than a NASA scientist analyzing images taken from outer space. In fact, NASA conducts global weather research using space-based observations to determine the possibility of major flooding or catastrophic storms.

Project
Electronic scanning multi-frequency radar for climate research.

Mission Directorate
Science

Phase III Success
Over $45M in non-SBIR and Phase III funding from government and commercial customers to convert SBIR R&D into products and product orders.

Snapshot
NASA scientists gain insight into our climate and cloud systems not possible before using a powerful new electronic scanning multi-frequency radar made from miniature parts created by Nuvotronics' PolyStrata® process.

Nuvotronics Inc.
2305 Presidential Drive
Durham, NC 27703
www.nuvotronics.com

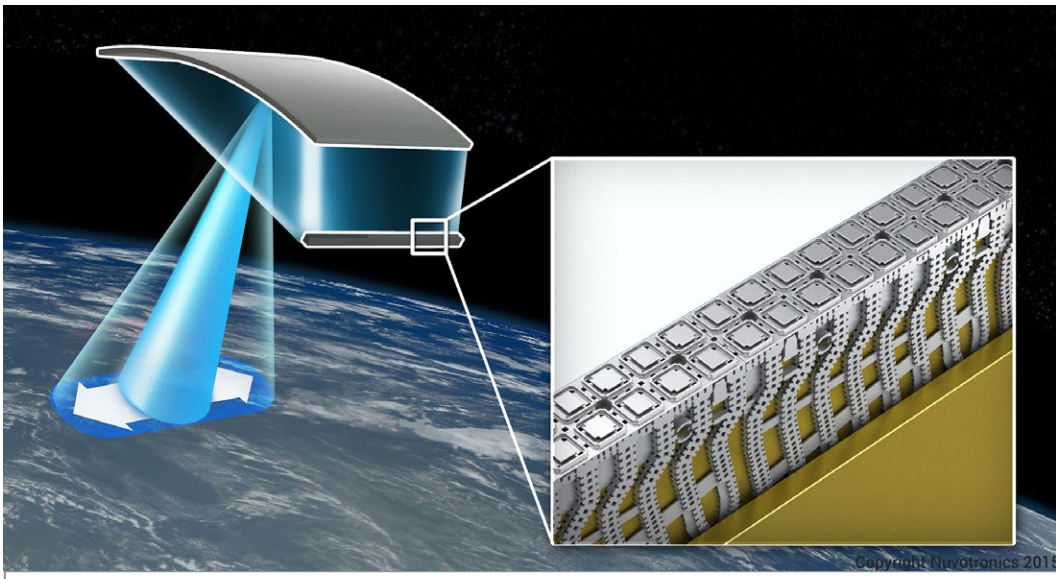
Scientists use radars, object-detection systems that transmit and receive radio waves, to gather data on clouds and precipitation in order to determine their impact on the weather and our climate. Cloud and precipitation studies had been limited until Nuvotronics Inc, through NASA's Small Business Innovation Research (SBIR) program, helped NASA realize its vision for an electronic scanning multi-frequency radar.

NASA's Jet Propulsion Laboratory needed a radar that could transmit radio waves to gather cloud data at multiple simultaneous frequencies. Lower frequency radars can penetrate rain very well to measure an entire storm from its highest top in the sky to the bottom where it touches the Earth. Higher frequencies are ideal to gather data on very thin clouds which are almost invisible at the lower frequencies. A multi-frequency electronic scanning radar that covers each frequency of interest would help climate scientists get a more comprehensive view of cloud systems and reduce the uncertainty of predicting precipitation.

In order to transmit radio waves at these higher frequencies, a radar composed of miniature components was required. The challenge NASA encountered was that the technology to make such a radar was not yet available. Nuvotronics Inc, a North Carolina-based firm, helped make NASA's concept for a multi-frequency radar a reality using its PolyStrata® process. This process can be used to produce fundamentally new and very small three-dimensional metallic and dielectric (having electrical insulating properties) structures for very high frequencies which were needed to build the radar and was the breakthrough NASA needed.

In addition to reaching higher frequencies, scientists can use this multi-frequency radar to conduct high-sensitivity measurements of multiple atmospheric phenomena over a significant area by reconfiguring it at different frequencies.

The genesis of the PolyStrata® technology came from a solution initially created for the Defense Advanced Research Projects Agency (DARPA), the US agency that develops emerging technologies for military use. DARPA recognized that the traditional communications channels were becoming congested and sought to explore underutilized extremely-high radio frequencies which required very small and precise antennas to transmit and receive signals. The ability of Nuvotronics Inc to create precisely-detailed electronics for miniature instruments was the perfect solution.



Conceptual model depicting an electronic scanning radar developed using PolyStrata® technology which can beam radio waves in different directions at multiple frequencies.

This success with DARPA led to Nuvotronics Inc developing a greenhouse gas radiometer using miniature parts for a NASA SBIR project and participation in three different NASA Earth Science Technology Office Instrument Incubator Program efforts.

Nuvotronics Inc is now collaborating with NASA to develop an antenna that incorporates transmit and receive modules to collect data at multiple frequencies simultaneously for target locations.

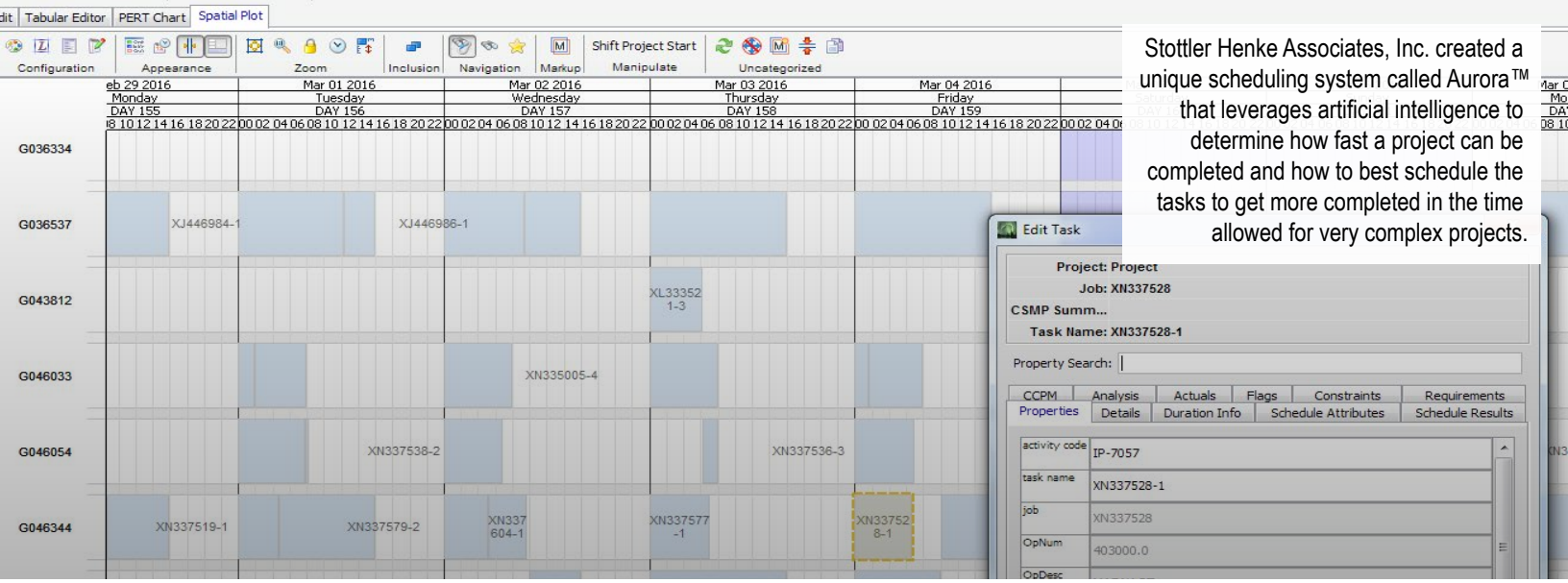
The ability of Nuvotronics Inc to produce instruments that are significantly smaller in size and lighter in weight also helps expand scientific research capacity. Nuvotronics Inc can make the antenna and other parts of the radar system including filters in batches which lowers production costs — allowing expenditure on other instruments needed for the mission or reducing launch cost by allowing integration on a smaller satellite platform.

Since its initial foray with DARPA and NASA, Nuvotronics Inc has generated custom solutions for communication and defense markets based on over 75 patents using the PolyStrata® microfabrication process.

> "The NASA SBIR program acted as a springboard after our initial success with DARPA. NASA's investment in PolyStrata® technology allowed us to think outside the box to identify new ways to innovate data gathering and communications instruments."
>
> **NUVOTRONICS, INC**
> Executive Vice President
> SCOTT MELLER

"The NASA SBIR program acted as a springboard after our initial success with DARPA. NASA's investment in PolyStrata® technology allowed us to think outside the box to identify new ways to innovate data gathering and communications instruments," explained Scott Meller, Executive VP, Nuvotronics Inc. "We are proud that the strong interest from our customers has fueled a 40% compound annual growth rate in our company over 7 years."

From Left to Right: Tim Smith - Lead Mechanical Engineer, Ben Cannon - Lead Electrical Engineer, and Ken Vanhille - Principal Investigator



Stottler Henke Associates, Inc. created a unique scheduling system called Aurora™ that leverages artificial intelligence to determine how fast a project can be completed and how to best schedule the tasks to get more completed in the time allowed for very complex projects.

STOTTLER HENKE ASSOCIATES, INC.

Building the International Space Station (ISS) is much like putting together a giant puzzle in space. Imagine the planning required to construct the ISS so far from Earth and prepare for launching the components to build the structure. In the past, NASA used common scheduling systems for similar complex missions to determine which tasks needed to be accomplished and when. This took a great deal of time and did not always result in the best approach.

Project
Complex scheduling software that leverages artificial intelligence.

Mission Directorate
Human Exploration and Operations

Commercialization Success
Over $13 million in follow on sales for artificial intelligence scheduling software based on SBIR contracts from NASA space centers. Customers include Boeing, Bombardier, Department of Defense, Honda, Lockheed Space, and Pfizer.

Snapshot
Aurora™, a sophisticated scheduling system used by NASA, combines a variety of scheduling techniques, intelligent conflict resolution, and decision support to make scheduling faster and easier.

Stottler Henke Associates, Inc.
1650 South Amphlett Boulevard
Suite 300
San Mateo, CA 94402
www.stottlerhenke.com

NASA needed sophisticated software to create multi-mission plans faster and more efficiently. Stottler Henke Associates, Inc., a San Mateo, California company, proposed using their unique scheduling system called Aurora™ to help NASA meet this need through its Small Business Innovation Research (SBIR) program. By leveraging artificial intelligence (AI), Aurora™ produces optimal scheduling to reduce risk and ensure space missions are launched on time.

Aurora™ was designed to make decisions, like humans, at a faster rate. The software's capability to enable NASA to analyze numerous what-if scenarios efficiently using AI technologies and apply extensive scheduling knowledge and rules is what gives it its edge.

"What differentiates Aurora™ from other scheduling software is that it mimics human thought processes to solve challenging problems. We have applied decades of research on human reasoning, tactical decision-making, and deliberative planning and scheduling to develop the software," according to Annaka Kalton, Stottler Henke Technical Lead. "The software achieves efficiency through iterations and considers a multitude of variables to generate the best scheduling option which is refined over time."

NASA is using Aurora™ for the Space Launch System (SLS) which is considered the world's most powerful rocket. SLS is designed to launch astronauts in NASA's Orion spacecraft on missions to an asteroid and eventually to Mars. In 2014, Stottler Henke was awarded a 28-month SBIR Phase II contract for ground processing optimization using AI techniques for SLS. A version of Aurora™, tailored to NASA Kennedy Space Center (KSC) activities, is now being used for scheduling of a future SLS test flight under the Phase III of the SBIR program.

NASA used Aurora™ to generate short-term and long-term (10 year) schedules of ground-based activities that prepared space shuttles before each mission and refurbished them after each mission.

"We are grateful for our relationship with NASA SBIR which spans over twenty-five years and we will continue to develop innovative breakthroughs for NASA's planning needs to keep space exploration on track."

STOTTLER HENKE ASSOCIATES, INC.
President
DICK STOTTLER

Stottler Henke has a long history of working with NASA dating back to 1992 when the company was awarded its first grant to solve scheduling challenges. Stottler Henke has further developed the AI-based software for two decades through SBIR programs which resulted in the creation of Aurora™. This system became operational at KSC in October 2003 when it was used to schedule floor space usage and other resources at the Space Station Processing Facility. NASA also used Aurora™ for maintenance, repair and overhaul of space shuttles.

In 2004, Stottler Henke reached a commercialization turning point after entering Boeing's worldwide search challenge to solve a scheduling problem for the 787 Dreamliner, the aerospace company's most fuel-efficient airliner. Aurora™ out-performed all the other competition participants including Boeing's scheduling solution at the time. This led to Stottler Henke being awarded a multimillion-dollar contract from Boeing to help realize manufacturing efficiencies by optimizing aircraft assembly schedules.

Born from America's space program twenty-five years ago, Aurora™ now helps a range of government agencies and companies which include Department of Defense, Boeing, General Dynamics, Learjet, and Partners Healthcare (Massachusetts General Hospital).

NASA is implementing Aurora™ to schedule the ground-based activities that are preparing the Space Launch System before its maiden flight.

Vanilla Aircraft's non-stop, unrefueled 56-hour test flight on November 30, 2016 was submitted for a world duration record for combustion-powered unmanned aerial vehicles (UAVs) in the 50-500 kilogram subclass.

VANILLA AIRCRAFT

NASA is at the forefront of exploring distant locations from outer space to remote territories on Earth. It takes ingenuity and innovative technology to reach these locations and send back information so we can learn about them. In an effort to improve our understanding of the Arctic and Antarctica, NASA sought a unique aircraft solution. This aircraft needed to fly a long distance without refueling to some of the coldest locations on the planet.

Project
Long endurance aircraft designed to operate in very cold conditions.

Mission Directorate
Science

Phase III Success
A DOD contract worth over $1 million to build an aircraft to improve ground communications in remote areas

Snapshot
Vanilla Aircraft designed a record-breaking aircraft that can travel far distances to collect data in very cold climates by innovating existing technologies through a joint effort funded by NASA and DOD

Vanilla Aircraft
2822 Mary Street
Falls Church, VA
www.vanillaaircraft.com

Vanilla Aircraft, a company in Falls Church, Virginia that specializes in long endurance unmanned aircraft systems (UAS), designed just the solution for NASA as part of the Small Business Innovation Research (SBIR) program. The aircraft, referred to as the VA001 UAS, can cover thousands of square miles of treacherous terrain in a single flight and withstand bone chilling temperatures dropping below –40 °F on one tank of fuel. The UAS is designed to carry instruments that can gather critical information on a continuous basis for research missions including cryospheric studies which explores locations on Earth where water is frozen into ice or snow.

This economical aircraft also helps save money. The Vanilla Aircraft UAS can complete longer missions than the typical UAS so fewer are needed. Fewer aircraft missions translates into reduced maintenance costs and crew support. One may think that a longer mission would require more fuel, but that's not the case with this UAS. This ultra-efficient aircraft consumes an unusually small amount of fuel per hour compared to most other aircraft, manned or unmanned.

"We focused on making an affordable UAS that was scalable to large operations, and pushed the performance boundaries by innovating around existing standard technologies. By leveraging our experience in long range aerodynamics, we used proven aircraft design techniques to accommodate commercially available diesel engines which had not been done before," according to Neil Boertlein, VA001 Chief Engineer.

Vanilla Aircraft found a way to incorporate an engine in their UAS that runs on jet grade fuel – referred to as JP8 – which is typically used by the US military to power Humvees and jet fighters. This type of fuel, which contains corrosion inhibitors and anti-icing additives, is crucial for conducting research in the Arctic or Antarctica. This was an important part of the aircraft design in order to travel in the toughest and coldest conditions.

The Vanilla Aircraft flight crew and New Mexico State University UAS test site crew with the VA001 aircraft after a world record duration flight.

The initial NASA SBIR funding to develop the Vanilla Aircraft UAS evolved into a partnership with U.S. Department of Defense (DOD) which was interested in using the aircraft for multiple mission scenarios. Once the craft design was finalized and built through NASA's SBIR program, Vanilla Aircraft received a DOD contract worth over $1 million to build a second prototype UAS and conduct test flights. These funds came from the Naval Air System Command and the Defense Advanced Research Projects Agency, a DOD agency responsible for the development of emerging technologies for use by the military.

> "NASA SBIR seed funding was critical for us to push the envelope on how far we could go in distance and performance for our UAS design."
>
> **VANILLA AIRCRAFT**
> President
> JEREMY NOVARA

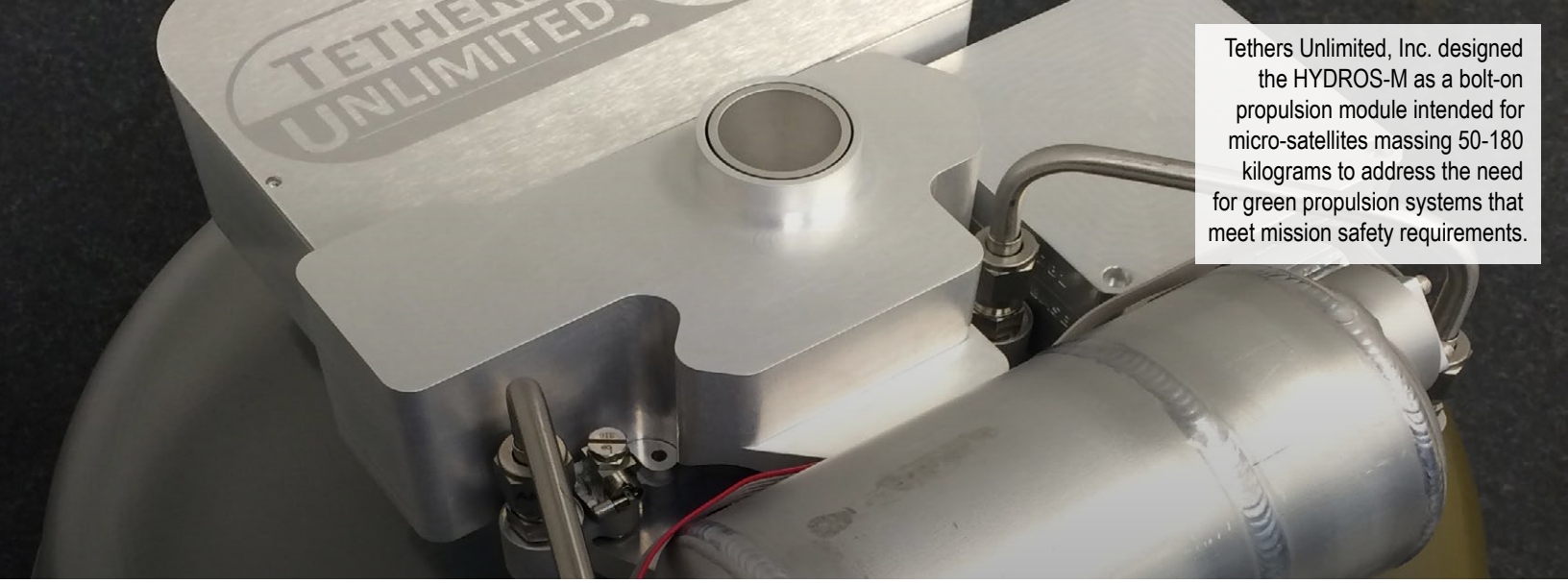
According to NASA Research Engineer Geoff Bland, "This is a very good example of how agencies can fund the same technology together to help achieve different goals."

A non-stop, unrefueled 56-hour test flight on November 30, 2016 not only proved Vanilla Aircraft could meet both NASA and DOD's needs, it also qualified for a world duration record for combustion-powered UAVs in the 50-500 kilogram subclass. The VA001 UAS carried 20 pounds of actual and simulated payload, flying at 6,500 to 7,500 feet above mean sea level on the test flight. This payload included a Naval Air Systems Command-provided relay which operated continuously throughout the flight to demonstrate communications functionality, and a NASA-provided multispectral imaging system to demonstrate remote sensing.

Vanilla Aircraft is working with manufacturers to build airframes based on the design developed under SBIR and plans to make these products available for commercial use next year.

"The SBIR seed funding was critical for us to push the envelope on how far we could go in distance and performance for our UAS design," according to Jeremy Novara, VA001 Program Manager. "NASA is playing a critical role in using UASs to conduct important research to better understand our world and we are thrilled that our UAS can help in this effort."

Timelapse photo of flight path taken during Vanilla Aircraft's record flight.



Tethers Unlimited, Inc. designed the HYDROS-M as a bolt-on propulsion module intended for micro-satellites massing 50-180 kilograms to address the need for green propulsion systems that meet mission safety requirements.

TETHERS UNLIMITED INC.

Satellites launched into space use small rocket engines called thrusters to change altitude or direction. Most satellite thrusters are powered by toxic fuels which are unsafe to handle. NASA sought assistance in building a propulsion system with thrusters powered by green propellants to reduce safety risks. Tethers Unlimited, Inc., a company based out of Bothell, WA, developed a unique thruster solution to meet this need as part of NASA's Small Business Innovative Research Program.

Project
CubeSat thrusters powered by green propellant.

Mission Directorate
STMD

Phase III
$2.2 million in contracts from NASA and Millennium Space Systems to test the HYDROS system prototype.

Snapshot
Tethers Unlimited, Inc. has pioneered a CubeSat thruster which uses a green propellant created from water-electrolysis for NASA space research and commercial ventures.

Tethers Unlimited, Inc.
11711 North Creek Parkway South
Suite D-113
Bothell,WA 98011
www.tethers.com

Tethers Unlimited, Inc.'s (TUI) green propulsion system called HYDROS is used to power CubeSats, a type of miniaturized satellite, which play a valuable role in NASA's science, technology, and educational investigations. These mini-satellites provide a low-cost platform for NASA science missions, including planetary exploration. TUI's efforts to make a safer propulsion system are also helping provide additional cost savings for government and commercial ventures by extending the CubeSat operational life and improving performance.

According to Karsten James, TUI's HYDROS effort project manager, "We developed a water-electrolysis propulsion solution that not only reduces safety risks but enables small satellites to perform longer and more complicated missions. Our technology provides long-duration thrusting to compensate for drag which can result in the satellite losing speed and altitude. Using HYDROS, a CubeSat that would last for a couple of months without propulsion can now stay in orbit for several years."

Weighing less than 1.33 kilograms (3 pounds) per one Unit (U) – the standard dimension of 10×10×11.35 centimeter cubic units – CubeSats are typically piggybacked as secondary payloads on primary launch vehicles. Once the host vehicle enters orbit, the CubeSat is ejected and embarks on its solitary journey.

Although gaining in popularity in recent years, CubeSats have typically been limited to missions that do not require propulsion. Traditional propulsion solutions that use toxic propellants contribute an increased risk to the launch

vehicle's primary payload. TUI, under a NASA Small Business Innovation Research (SBIR) Phase II program, designed a propulsion system to address safety risks and CubeSat limitations. HYDROS, which combines an electrolysis cell designed for microgravity with a small but reliable bipropellant thruster, enables a CubeSat to be launched with no stored energy.

HYDROS-C is a 20x10x10 centimeter module sized for CubeSats and nano-satellite propulsion systems.

The HYDROS propulsion system uses two elements to provide safe CubeSat propulsion – water and the sun. Measuring about 4 inches wide, the TUI thrusters run on hydrogen and oxygen which are produced in space by splitting water molecules using solar-powered electrolysis. The hydrogen and oxygen gases are burned in the thrusters to propel satellites during maneuvers.

CubeSats also require propulsion capabilities to carry out more useful endeavors that compete with larger missions. TUI's thruster propulsion design gives the micro-satellite the capability of performing large and rapid orbital maneuvers. This added propulsion enables the CubeSats to change speed to alter its position or path to counteract drag caused by air resistance in the atmosphere.

> "From providing SBIR seed money to help develop our innovative propulsion design to funding prototype production through the Tipping Point contract, we are proud that NASA has been with us for the entire journey of creating HYDROS."
>
> **TETHERS UNLIMITED INC.**
> CEO & Chief Scientist
> ROBERT P. HOYT PH.D.

CubeSats are an attractive proposition for research projects that cannot justify the cost of a larger satellite mission. They are used to conduct experiments by academic institutions such as the Air Force Institute of Technology (AFIT) which has purchased several of TUI's HYDROS thrusters due to its safety benefits. This low-risk option is preferable over thrusters that use hazardous propellant for the Air Force cadets to conduct research.

The proliferation of secondary payload flight opportunities using CubeSats has benefited the private sector as well. Companies are turning to these small satellites as an efficient way to conduct research, such as collecting Earth imaging data and weather tracking. TUI is in an optimum position to meet the CubeSat needs of private sector customers with its novel approach to propulsion. By reducing safety risks to the primary payload by using the HYDROS system, there are more opportunities for CubeSats to be included on expensive missions.

TUI won $2.2 million in contracts from NASA and Millennium Space Systems (MSS) through NASA's Tipping Point Program to deliver two different HYDROS thruster prototypes – a "HYDROS-C" module sized for CubeSats massing 10 kilograms and a larger "HYDROS-M" module sized for micro-satellites massing 50-180 kilograms. Under this public-private partnership, TUI plans to deliver a flight-ready HYDROS-C thruster for testing on a CubeSat mission as part of NASA's Pathfinder Technology Demonstration Program at NASA Ames Research Center. TUI will also provide three HYDROS-M thrusters – sized for MSS' ALTAIR™ class micro-satellites – to support three different flight missions.

"From providing SBIR seed money to help develop our innovative propulsion design to funding prototype production through the Tipping Point contract, NASA has provided key support for the entire journey of creating HYDROS," said TUI's CEO & Chief Scientist Robert Hoyt. "Looking to the future, we plan to explore the use of the HYDROS technology to enable water obtained from asteroids and the Moon to propel the next generation of spacecraft."

The Rice Decision Support System (RiceDDS) provides mapping services to support NASA's contribution to the Group on Earth Observations Global Agricultural Monitoring Initiative (GEOGLAM) which produces and disseminates timely and accurate forecasts of agricultural production using Earth Observation data.

APPLIED GEOSOLUTIONS

Over 3.5 billion people depend on rice to survive. In addition to being a major food staple, rice has far-reaching economic implications. Tools to monitor rice production and manage risks associated with growing the crop are needed by farmers, investors, and governments. However, it wasn't until Applied GeoSolutions developed a Rice Decision Support System (RiceDSS) for NASA's small business innovation research (SBIR) program that improvements to real-time rice production forecasting and condition assessment was possible.

Project
Rice Decision Support System (RiceDSS)

Mission Directorate
Science

Phase III Success
Raised approximately $2.5 million in post Phase II (includes Phase II-X and Phase III funds) from NASA, international aid agencies and the private sector.

Snapshot
Applied GeoSolutions' real-time rice mapping and production forecasting tool piloted in the United States through SBIR is being further developed for a multi-million dollar initiative to reduce greenhouse gas emissions in Vietnam.

Applied GeoSolutions
87 Packers Falls Rd
Durham, NH 03824
www.appliedgeosolutions.com

To support both the rice futures market and NASA food security missions, Applied GeoSolutions is leveraging satellite imagery to generate information about rice growth, water management and expected yields around the globe. In the past, data on rice growing efforts were typically obtained by surveying farmers which could take days or weeks to collect information. More recently, Earth Observation data from satellites has transformed data collection, making quick analysis possible within hours of overpass collection.

"Timeliness is a key factor. Although satellite mapping of rice paddies has been available, translating vast amounts of optical and synthetic aperture radar imagery into consistent and meaningful information in a timely manner has been a big challenge," according to Applied GeoSolutions President William Salas. "Our RiceDSS application solves the problem by generating and delivering high resolution rice maps and timely rice production forecasts at state to national scale. We can now collect and analyze near real time data at time intervals only possible due to recent proliferation of Earth Observation satellites."

For more than a decade Applied GeoSolutions, based in Dunham, New Hampshire, researched various applications for Earth-imaging satellite data. The company's foray into rice research started with developing mathematical calculations to estimate greenhouse gas emissions associated with rice cultivation. Building on its use of mathematical modeling, Applied GeoSolutions developed an approach to monitor conditions and calculate risks to the global food supply by forecasting rice production.

The company's RiceDSS application provides timely information on how much rice has been planted and how well it is growing. This is a game changer

for the agricultural sector, food monitoring programs and the commodity markets. The analysis of rice cultivation generated by RiceDSS can be used to quickly adjust to market needs and pricing as well as hedge a number risks associated with crop failure or low production.

Satellite remote sensing provides an important opportunity to consistently and broadly observe thousands of farm fields. Applied GeoSolutions found a way to leverage daily data streams of calibrated satellite remote sensing observations and combine with near real time estimates from crop models and short and mid-term weather forecasts.

RiceDSS was developed to provide improved monitoring of rice agriculture to generate near real time information on rice growth stages, production forecasts and statistical uncertainty.

This powerful analysis improved predictions of rice yields and production at scales ranging from individual farm fields to large regions. State-of-the-art open source web-geographic information system and mobile technologies that includes mobile devices ("smartphone app"), and online analyses modules are used to organize, visualize, and deliver this critical information to decision makers.

"SBIR provided us with a unique opportunity to help promote economic stability while addressing key humanitarian issues associated with the global food supply system. With this success, we are further developing RiceDDS to be used for commercialization in a number of ways."

APPLIED GEOSOLUTIONS
President
WILLIAM SALAS

As part of the SBIR program, Applied GeoSolutions developed and tested prototype RiceDDS in Arkansas and California. Farmers were provided with critical, time sensitive information through automated rice growth updates at weekly intervals which was a vast improvement to the standard monthly reports. Armed with this information, farmers can now monitor crop health in near real time throughout the growing season to help develop crop management plans.

This comprehensive forecasting is possible because Applied GeoSolutions collects data from multiple sources very early in the growing season. Data from Landsat 7 and 8 satellites, which capture images of the Earth's surface every 8 days, are combined with data from MODIS, a satellite which maps Earth every day, and satellites with new radar sensors, like Sentinel-1 and PALSAR-2. This allows for better monitoring of changes in crop stages, plants' responses to weather, and farm activities such as irrigation or tillage.

RiceDDS is now being used in Southeast Asia through AgResults, a $118 million multilateral initiative financed jointly by the governments of Australia, Canada, the United Kingdom, the United States, and the Bill & Melinda Gates Foundation. Applied GeoSolutions was selected as the lead verifier role for a AgResults Vietnam Emissions Reduction Pilot (AVERP) project to provide low cost, low touch verification of rice management practices in Thai Binh Province. Through AVERP, Applied GeoSolutions will help improve small farmer livelihood while increasing yields and curbing greenhouse gas emission.

RiceDSS generates and delivers high resolution, georeferenced rice monitoring maps and rice yield forecast maps that are driven by calibrated satellite remote sensing observations and short and mid-term weather forecasts.

According to Salas, "SBIR provided us with a unique opportunity to help promote economic stability while addressing key humanitarian issues associated with climate change and global food supply system. With this success, we are further developing RiceDDS to be used for commercialization in a number of ways. We are planning to provide consulting services which leverage the use of forecasts to optimize efficiency and support adaptation and mitigation strategies."

MISSION DIRECTORATE & TECHNOLOGY AREA INVESTMENTS

NASA SBIR invests in many different research areas. The following tables break down the program's Phase I and Phase II investments into two views:

1. Mission Directorate Investments by Technology or Topic Area FY2016
2. Mission Directorate Investments by Technology or Topic Area FY2012-2016 (showing 5-year history)

FY2016 Phase I & II Awards

Table 1: HEOMD Investments by Technology Area (FY2016)

TA Level 1	TA Level 2	Award Amount	# of Awards
1.0.0 Launch Propulsion Systems	1.2.0 Liquid Rocket Propulsion Systems	$124,962	1
1.0.0 Launch Propulsion Systems Total		**$124,962**	**1**
2.0.0 In-Space Propulsion Technologies	2.1.0 Chemical Propulsion	$1,364,890	6
	2.2.0 Non-Chemical Propulsion	$1,236,877	5
	2.4.0 Supporting Technologies	$1,747,077	4
2.0.0 In-Space Propulsion Technologies Total		**$4,348,844**	**15**
3.0.0 Space Power & Energy Storage	3.1.0 Power Generation	$2,744,971	12
	3.2.0 Energy Storage	$499,728	4
3.0.0 Space Power & Energy Storage Total		**$3,244,699**	**16**
4.0.0 Robotics, Telerobotics & Autonomous Systems	4.1.0 Sensing & Perception	$749,989	1
	4.2.0 Mobility	$998,399	3
	4.3.0 Manipulation	$1,116,728	4
	4.5.0 Autonomy	$363,547	3
	4.7.0 RTA Systems Engineering	$754,880	1
4.0.0 Robotics, Telerobotics & Autonomous Systems Total		**$3,983,543**	**12**
5.0.0 Communication & Navigation	5.1.0 Optical Comm. & Navigation	$2,929,292	8
	5.2.0 Radio Frequency Communications	$368,594	3
	5.4.0 Position, Navigation & Timing	$374,608	3
5.0.0 Communication & Navigation Total		**$3,672,494**	**14**
6.0.0 Human Health, Life Support & Habitation Systems	6.1.0 Environmental Control Life Support & Habitation Systems	$2,755,553	7
	6.2.0 Extravehicular Activity Systems	$3,803,408	11
	6.3.0 Human Health & Performance	$2,871,748	8

TA Level 1	TA Level 2	Award Amount	# of Awards
	6.4.0 Environmental Monitoring & Safety	$3,238,844	11
	6.5.0 Radiation	$2,365,011	4
6.0.0 Human Health, Life Support & Habitation Systems Total		**$15,034,564**	**41**
7.0.0 Human Exploration Destination Systems	7.1.0 In-Site Resource Utilization	$3,112,027	10
	7.4.0 Advanced Habitat Systems	$755,000	1
	7.5.0 Mission Operations & Safety	$249,863	2
7.0.0 Human Exploration Destination Systems Total		**$4,116,890**	**13**
8.0.0 Science Instruments, Observatories & Sensor Systems	8.1.0 Science Instruments	$1,374,458	6
8.0.0 Science Instruments, Observatories & Sensor Systems Total		**$1,374,458**	**6**
9.0.0 Entry, Descent & Landing Systems	9.1.0 Aeroassist & Entry	$3,608,911	9
	9.4.0 Vehicle Systems Technology	$120,735	1
9.0.0 Entry, Descent & Landing Systems Total		**$3,729,646**	**10**
11.0.0 Modeling, Simulation, Information Technology & Processing	11.2.0 Modeling	$125,000	1
11.0.0 Modeling, Simulation, Information Technology & Processing Total		**$125,000**	**1**
12.0.0 Materials, Structures, Mechanical Systems & Manufacturing	12.1.0 Materials	$997,879	3
	12.2.0 Structures	$3,373,272	12
	12.3.0 Mechanical Systems	$248,807	2
	12.4.0 Manufacturing	$2,629,370	6
	12.5.0 Cross-Cutting	$1,370,797	6
12.0.0 Materials, Structures, Mechanical Systems & Manufacturing Total		**$8,620,125**	**29**
13.0.0 Ground & Launch Systems Processing	13.1.0 Technologies to Optimize the Operational Life-Cycle	$2,125,993	7
13.0.0 Ground & Launch Systems Processing Total		**$2,125,993**	**7**
14.0.0 Thermal Management Systems	14.1.0 Cryogenic Systems	$1,001,644	3
	14.2.0 Thermal Control Systems	$749,108	1
	14.3.0 Thermal Protection Systems	$124,998	1
14.0.0 Thermal Management Systems Total		**$1,875,750**	**5**
Grand Total		**$52,376,968**	**170**

Table 2: SMD Investments by Technology Area (FY2016)

TA Level 1	TA Level 2	Award Amount	# of Awards
1.0.0 Launch Propulsion Systems	1.1.0 Solid Rocket Propulsion Systems	$249,226	2
	1.5.0 Unconventional/Other Propulsion Systems	$124,812	1
1.0.0 Launch Propulsion Systems Total		**$374,038**	**3**
2.0.0 In-Space Propulsion Technologies	2.1.0 Chemical Propulsion	$2,750,383	12
	2.2.0 Non-Chemical Propulsion	$249,886	2
	2.3.0 Advanced (TRL <3) Propulsion Technologies	$749,645	1
	2.4.0 Supporting Technologies	$749,900	1
2.0.0 In-Space Propulsion Technologies Total		**$4,499,814**	**16**
3.0.0 Space Power & Energy Storage	3.1.0 Power Generation	$2,247,384	8
	3.2.0 Energy Storage	$118,906	1
	3.3.0 Power Management & Distribution	$2,374,774	9
3.0.0 Space Power & Energy Storage Total		**$4,741,064**	**18**
4.0.0 Robotics, Telerobotics & Autonomous Systems	4.2.0 Mobility	$2,113,898	7
	4.3.0 Manipulation	$123,628	1
	4.5.0 Autonomy	$754,805	1
	4.7.0 RTA Systems Engineering	$999,833	3
4.0.0 Robotics, Telerobotics & Autonomous Systems Total		**$3,992,164**	**12**
5.0.0 Communication & Navigation	5.2.0 Radio Frequency Communications	$249,924	2
	5.4.0 Position, Navigation & Timing	$1,876,659	5
5.0.0 Communication & Navigation Total		**$2,126,583**	**7**
6.0.0 Human Health, Life Support & Habitation Systems	6.5.0 Radiation	$124,714	1
6.0.0 Human Health, Life Support & Habitation Systems Total		**$124,714**	**1**
8.0.0 Science Instruments, Observatories & Sensor Systems	8.1.0 Science Instruments	$22,694,344	60
	8.2.0 Observations	$1,747,844	9
	8.3.0 Sensor Systems	$7,852,801	28
8.0.0 Science Instruments, Observatories & Sensor Systems Total		**$32,294,989**	**97**
9.0.0 Entry, Descent & Landing Systems	9.1.0 Aeroassist & Entry	$124,980	1
	9.2.0 Descent	$986,409	3
	9.3.0 Landing	$249,960	2
9.0.0 Entry, Descent & Landing Systems Total		**$1,361,349**	**6**

TA Level 1	TA Level 2	Award Amount	# of Awards
11.0.0 Modeling, Simulation, Information Technology & Processing	11.1.0 Computing	$2,002,884	6
	11.2.0 Modeling	$107,894	1
	11.4.0 Information Processing	$1,867,541	5
11.0.0 Modeling, Simulation, Information Technology & Processing Total		**$3,978,319**	**12**
12.0.0 Materials, Structures, Mechanical Systems & Manufacturing	12.2.0 Structures	$749,933	1
	12.3.0 Mechanical Systems	$124,827	1
12.0.0 Materials, Structures, Mechanical Systems & Manufacturing Total		**$874,760**	**2**
14.0.0 Thermal Management Systems	14.1.0 Cryogenic Systems	$249,605	2
	14.2.0 Thermal Control Systems	$2,128,312	7
	14.3.0 Thermal Protection Systems	$124,955	1
14.0.0 Thermal Management Systems Total		**$2,502,872**	**10**
Grand Total		**$56,870,666**	**184**

Table 3: STMD Investments by Technology Area (FY2016)

TA Level 1	TA Level 2	Award Amount	# of Awards
3.0.0 Space Power & Energy Storage	3.1.0 Power Generation	$749,999	1
	3.3.0 Power Management & Distribution	$369,001	3
	3.4.0 Cross Cutting Technology	$865,433	2
3.0.0 Space Power & Energy Storage Total		**$1,984,433**	**6**
4.0.0 Robotics, Telerobotics & Autonomous Systems	4.4.0 Human-Systems Integration	$373,982	3
4.0.0 Robotics, Telerobotics & Autonomous Systems Total		**$373,982**	**3**
6.0.0 Human Health, Life Support & Habitation Systems	6.4.0 Environmental Monitoring & Safety	$249,977	2
6.0.0 Human Health, Life Support & Habitation Systems Total		**$249,977**	**2**
11.0.0 Modeling, Simulation, Information Technology & Processing	11.2.0 Modeling	$754,220	1
11.0.0 Modeling, Simulation, Information Technology & Processing Total		**$754,220**	**1**
12.0.0 Materials, Structures, Mechanical Systems & Manufacturing	12.1.0 Materials	$124,999	1
	12.2.0 Structures	$124,939	1
	12.4.0 Manufacturing	$2,744,323	7
12.0.0 Materials, Structures, Mechanical Systems & Manufacturing Total		**$2,994,261**	**9**
14.0.0 Thermal Management Systems	14.2.0 Thermal Control Systems	$499,754	4
14.0.0 Thermal Management Systems Total		**$499,754**	**4**
Grand Total		**$6,856,627**	**25**

Table 4: ARMD Investments by Topic Area and Subtopic Area (FY2016)

Topic Area	Subtopic Area	Award Amount	# of Awards
Air Vehicle Technology	Aerodynamic Efficiency - Active Flow Control Actuation Concepts	$499,837	4
	Aerodynamic Efficiency Drag Reduction Technology	$754,892	1
	Aeronautics Ground Test and Measurements Technologies - Ground Test & Measurements Technologies	$499,675	4
	Efficient Propulsion & Power	$754,984	1
	Ground Testing & Measurement Technologies	$2,259,613	3
	Low Emissions Propulsion & Power	$2,277,709	3
	Low Emissions/Clean Power - Combustion Technology/Emissions Measurement Techniques	$374,926	3
	Physics-Based Computational Tools - Stability & Control/High Lift Design Tools	$371,391	3
	Physics-Based Conceptual Aeronautics Design Tools	$749,767	1
	Propulsion Efficiency - Turbomachinery Technology for Reduced Fuel Burn	$497,492	4
	Quiet Performance	$752,273	1
	Quiet Performance - Propulsion Noise Reduction Technology	$498,539	4
	Structural Efficiency - Aeroelasticity & Aeroservoelastic Control	$624,884	5
	Structural Efficiency-Hybrid Nanocomposites	$749,954	1
	Vehicle Safety - Inflight Icing Hazard Mitigation Technology	$495,948	4
	Vertical Lift	$749,930	1
	Vertical Lift - VL Measurement Techniques & Condition-Based Maintenance	$370,624	3
Air Vehicle Technology Total		**$13,282,438**	**46**
Airspace Operations & Safety	Advanced Air Traffic Management Systems Concepts	$2,871,317	8
	Autonomy of the National Airspace System (NAS)	$4,489,672	6
	Autonomy of the National Airspace Systems (NAS)	$991,228	8
	Future Aviation Systems Safety	$1,466,371	7
Airspace Operations & Safety Total		**$9,818,588**	**29**
Integrated Flight Systems	Flight Test & Measurements Technologies	$3,369,668	12
	Unmanned Aircraft Systems Technology	$5,595,596	15
Integrated Flight Systems Total		**$8,965,264**	**27**
Grand Total		**$32,066,290**	**102**

FY2012-2016 Phase I & II Awards

Table 5: HEOMD Investments by Technology Area (FY2012-2016)

TA Level 1	TA Level 2	Award Amount	# of Awards
1.0.0 Launch Propulsion Systems	1.1.0 Solid Rocket Propulsion Systems	$750,000	1
	1.2.0 Liquid Rocket Propulsion Systems	$4,516,454	12
	1.4.0 Ancillary Propulsion Systems	$237,522	2
	1.5.0 Unconventional/Other Propulsion Systems	$499,475	4
1.0.0 Launch Propulsion Systems Total		**$6,003,451**	**19**
2.0.0 In-Space Propulsion Technologies	2.1.0 Chemical Propulsion	$9,446,338	35
	2.2.0 Non-Chemical Propulsion	$12,902,670	37
	2.3.0 Advanced (TRL <3) Propulsion Technologies	$749,958	1
	2.4.0 Supporting Technologies	$6,622,279	18
2.0.0 In-Space Propulsion Technologies Total		**$29,721,245**	**91**
3.0.0 Space Power & Energy Storage	3.1.0 Power Generation	$16,849,315	49
	3.2.0 Energy Storage	$3,541,555	18
	3.3.0 Power Management & Distribution	$124,597	1
3.0.0 Space Power & Energy Storage Total		**$20,515,467**	**68**
4.0.0 Robotics, Telerobotics & Autonomous Systems	4.1.0 Sensing & Perception	$1,488,631	7
	4.2.0 Mobility	$2,123,383	7
	4.3.0 Manipulation	$5,023,842	14
	4.4.0 Human-Systems Integration	$4,321,675	9
	4.5.0 Autonomy	$5,038,608	14
	4.6.0 Autonomous Rendezvous & Docking	$874,991	2
	4.7.0 RTA Systems Engineering	$1,879,464	5
4.0.0 Robotics, Telerobotics & Autonomous Systems Total		**$20,750,594**	**58**
5.0.0 Communication & Navigation	5.1.0 Optical Comm. & Navigation	$10,077,866	32
	5.2.0 Radio Frequency Communications	$3,260,097	15
	5.3.0 Internetworking	$872,755	2
	5.4.0 Position, Navigation, & Timing	$4,515,747	16
	5.5.0 Integrated Technologies	$2,448,605	9
	5.6.0 Revolutionary Concepts	$238,729	2
5.0.0 Communication & Navigation Total		**$21,413,799**	**76**
6.0.0 Human Health, Life Support & Habitation Systems	6.1.0 Environmental Control Life Support & Habitation Systems	$14,650,355	54
	6.2.0 Extravehicular Activity Systems	$10,450,939	40

TA Level 1	TA Level 2	Award Amount	# of Awards
	6.3.0 Human Health & Performance	$20,361,450	53
	6.4.0 Environmental Monitoring & Safety	$8,141,927	29
	6.5.0 Radiation	$6,064,045	19
6.0.0 Human Health, Life Support & Habitation Systems Total		**$59,668,716**	**195**
7.0.0 Human Exploration Destination Systems	7.1.0 In-Site Resource Utilization	$11,398,513	41
	7.2.0 Sustainability & Supportability	$2,956,198	8
	7.3.0 Advanced Human Mobility Systems	$1,498,698	2
	7.4.0 Advanced Habitat Systems	$1,004,863	3
	7.5.0 Mission Operations & Safety	$748,787	6
7.0.0 Human Exploration Destination Systems Total		**$17,607,059**	**60**
8.0.0 Science Instruments, Observatories & Sensor Systems	8.1.0 Science Instruments	$4,898,332	14
	8.3.0 Sensor Systems	$774,945	5
8.0.0 Science Instruments, Observatories & Sensor Systems Total		**$5,673,277**	**19**
9.0.0 Entry, Descent & Landing Systems	9.1.0 Aeroassist & Entry	$11,214,572	35
	9.2.0 Descent	$873,563	2
	9.4.0 Vehicle Systems Technology	$495,728	4
9.0.0 Entry, Descent & Landing Systems Total		**$12,583,863**	**41**
10.0.0 Nanotechnology	10.4.0 Electronics, Sensors & Devices	$2,503,231	5
10.0.0 Nanotechnology Total		**$2,503,231**	**5**
11.0.0 Modeling, Simulation, Information Technology & Processing	11.1.0 Computing	$1,118,404	4
	11.2.0 Modeling	$1,464,463	7
	11.3.0 Simulation	$124,823	1
	11.4.0 Information Processing	$1,499,587	2
11.0.0 Modeling, Simulation, Information Technology & Processing Total		**$4,207,277**	**14**
12.0.0 Materials, Structures, Mechanical Systems & Manufacturing	12.1.0 Materials	$4,598,513	22
	12.2.0 Structures	$8,850,163	35
	12.3.0 Mechanical Systems	$2,123,270	7
	12.4.0 Manufacturing	$8,877,365	23
	12.5.0 Cross-Cutting	$5,703,960	17
12.0.0 Materials, Structures, Mechanical Systems & Manufacturing Total		**$30,153,271**	**104**
13.0.0 Ground & Launch Systems Processing	13.1.0 Technologies to Optimize the Operational Life-Cycle	$2,250,959	8

TA Level 1	TA Level 2	Award Amount	# of Awards
	13.2.0 Environmental & Green Technologies	$824,996	2
	13.3.0 Technologies to Increase Reliability & Mission Availability	$2,697,269	7
	13.4.0 Technologies to Improve Mission Safety/Mission Risk	$936,134	7
13.0.0 Ground & Launch Systems Processing Total		**$6,709,358**	**24**
14.0.0 Thermal Management Systems	14.1.0 Cryogenic Systems	$2,826,278	13
	14.2.0 Thermal Control Systems	$5,992,981	16
	14.3.0 Thermal Protection Systems	$124,998	1
14.0.0 Thermal Management Systems Total		**$8,944,257**	**30**
Not Mapped Level 1	Not Mapped Level 2	$4,606,487	16
Not Mapped Level 1 Total		$4,606,487	16
Grand Total		**$251,061,352**	**820**

Table 6: SMD Investments by Technology Area (FY2012-2016)

TA Level 1	TA Level 2	Award Amount	# of Awards
1.0.0 Launch Propulsion Systems	1.1.0 Solid Rocket Propulsion Systems	$374,226	3
	1.5.0 Unconventional/Other Propulsion Systems	$124,812	1
1.0.0 Launch Propulsion Systems Total		**$499,038**	**4**
2.0.0 In-Space Propulsion Technologies	2.1.0 Chemical Propulsion	$8,507,485	38
	2.2.0 Non-Chemical Propulsion	$7,826,087	16
	2.3.0 Advanced (TRL <3) Propulsion Technologies	$749,645	1
	2.4.0 Supporting Technologies	$2,098,943	5
2.0.0 In-Space Propulsion Technologies Total		**$19,182,160**	**60**
3.0.0 Space Power & Energy Storage	3.1.0 Power Generation	$9,671,754	30
	3.2.0 Energy Storage	$836,014	7
	3.3.0 Power Management & Distribution	$6,917,249	23
3.0.0 Space Power & Energy Storage Total		**$17,425,017**	**60**
4.0.0 Robotics, Telerobotics & Autonomous Systems	4.1.0 Sensing & Perception	$499,555	4
	4.2.0 Mobility	$3,307,127	16
	4.3.0 Manipulation	$2,240,194	5

TA Level 1	TA Level 2	Award Amount	# of Awards
	4.4.0 Human-Systems Integration	$124,783	1
	4.5.0 Autonomy	$2,741,153	7
	4.6.0 Autonomous Rendezvous & Docking	$1,879,627	2
	4.7.0 RTA Systems Engineering	$1,248,231	5
4.0.0 Robotics, Telerobotics & Autonomous Systems Total		**$12,040,670**	**40**
5.0.0 Communication & Navigation	5.2.0 Radio Frequency Communications	$498,120	4
	5.4.0 Position, Navigation, & Timing	$6,328,016	19
	5.5.0 Integrated Technologies	$738,659	1
5.0.0 Communication & Navigation Total		**$7,564,795**	**24**
6.0.0 Human Health, Life Support & Habitation Systems	6.5.0 Radiation	$124,714	1
6.0.0 Human Health, Life Support & Habitation Systems Total		**$124,714**	**1**
7.0.0 Human Exploration Destination Systems	7.5.0 Mission Operations & Safety	$115,520	1
7.0.0 Human Exploration Destination Systems Total		**$115,520**	**1**
8.0.0 Science Instruments, Observatories & Sensor Systems	8.1.0 Science Instruments	$79,732,279	217
	8.2.0 Observations	$13,379,205	39
	8.3.0 Sensor Systems	$26,166,246	85
	Not Mapped	$125,000	1
8.0.0 Science Instruments, Observatories & Sensor Systems Total		**$119,402,730**	**342**
9.0.0 Entry, Descent & Landing Systems	9.1.0 Aeroassist & Entry	$249,977	2
	9.2.0 Descent	$986,409	3
	9.3.0 Landing	$1,189,319	5
	9.4.0 Vehicle Systems Technology	$2,489,728	5
9.0.0 Entry, Descent & Landing Systems Total		**$4,915,433**	**15**
10.0.0 Nanotechnology	10.4.0 Electronics, Sensors & Devices	$699,821	1
10.0.0 Nanotechnology Total		**$699,821**	**1**
11.0.0 Modeling, Simulation, Information Technology & Processing	11.1.0 Computing	$5,002,761	14
	11.2.0 Modeling	$4,754,678	16
	11.3.0 Simulation	$1,124,029	4
	11.4.0 Information Processing	$7,719,184	20
11.0.0 Modeling, Simulation, Information Technology & Processing Total		**$18,600,652**	**54**
12.0.0 Materials, Structures, Mechanical Systems & Manufacturing	12.1.0 Materials	$229,010	2

TA Level 1	TA Level 2	Award Amount	# of Awards
	12.2.0 Structures	$749,933	1
	12.3.0 Mechanical Systems	$1,004,577	3
	12.4.0 Manufacturing	$624,447	5
12.0.0 Materials, Structures, Mechanical Systems & Manufacturing Total		**$2,607,967**	**11**
13.0.0 Ground & Launch Systems Processing	13.3.0 Technologies to Increase Reliability & Mission Availability	$124,037	1
13.0.0 Ground & Launch Systems Processing Total		**$124,037**	**1**
14.0.0 Thermal Management Systems	14.1.0 Cryogenic Systems	$2,523,075	9
	14.2.0 Thermal Control Systems	$6,746,328	24
	14.3.0 Thermal Protection Systems	$124,955	1
14.0.0 Thermal Management Systems Total		**$9,394,358**	**34**
Not Mapped Level 1	Not Mapped Level 2	$29,696,375	140
Not Mapped Level 1 Total		$29,696,375	140
Grand Total		**$242,393,287**	**788**

Table 7: STMD Investments by Technology Area (FY2012-2016)

TA Level 1	TA Level 2	Award Amount	# of Awards
2.0.0 In-Space Propulsion Technologies	2.2.0 Non-Chemical Propulsion	$1,868,955	4
	2.4.0 Supporting Technologies	$124,927	1
2.0.0 In-Space Propulsion Technologies Total		**$1,993,882**	**5**
3.0.0 Space Power & Energy Storage	3.1.0 Power Generation	$3,501,296	12
	3.2.0 Energy Storage	$2,513,551	10
	3.3.0 Power Management & Distribution	$369,001	3
	3.4.0 Cross Cutting Technology	$1,615,389	3
3.0.0 Space Power & Energy Storage Total		**$7,999,237**	**28**
4.0.0 Robotics, Telerobotics & Autonomous Systems	4.3.0 Manipulation	$1,129,387	4
	4.4.0 Human-Systems Integration	$373,982	3
4.0.0 Robotics, Telerobotics & Autonomous Systems Total		**$1,503,369**	**7**
5.0.0 Communication & Navigation	5.1.0 Optical Comm. & Navigation	$1,622,965	2
	5.4.0 Position, Navigation & Timing	$373,987	3
5.0.0 Communication & Navigation Total		**$1,996,952**	**5**

TA Level 1	TA Level 2	Award Amount	# of Awards
6.0.0 Human Health, Life Support & Habitation Systems	6.4.0 Environmental Monitoring & Safety	$249,977	2
6.0.0 Human Health, Life Support & Habitation Systems Total		**$249,977**	**2**
9.0.0 Entry, Descent & Landing Systems	9.1.0 Aeroassist & Entry	$124,703	1
9.0.0 Entry, Descent & Landing Systems Total		**$124,703**	**1**
11.0.0 Modeling, Simulation, Information Technology & Processing	11.2.0 Modeling	$1,132,002	4
11.0.0 Modeling, Simulation, Information Technology & Processing Total		**$1,132,002**	**4**
12.0.0 Materials, Structures, Mechanical Systems & Manufacturing	12.1.0 Materials	$504,245	4
	12.2.0 Structures	$373,575	3
	12.4.0 Manufacturing	$3,112,536	10
12.0.0 Materials, Structures, Mechanical Systems & Manufacturing Total		**$3,990,356**	**17**
14.0.0 Thermal Management Systems	14.2.0 Thermal Control Systems	$499,754	4
14.0.0 Thermal Management Systems Total		**$499,754**	**4**
Grand Total		**$19,490,232**	**73**

Table 8: ARMD Investments by Topic Area (FY2012-2016)

Topic Area	Award Amount	# of Awards
Aeronautics Research Mission Directorate Select Subtopics	$2,493,770	4
Aeronautics Test Technologies	$3,574,392	9
Air Traffic Management Research & Development (ATM R&D)	$6,670,351	19
Air Vehicle Technology	$38,499,456	139
Airspace Operations & Safety	$12,559,771	51
Airspace Systems	$5,674,738	14
Aviation Safety	$19,782,302	57
Fundamental Aeronautics	$13,155,140	39
Ground & Flight Test Techniques & Measurement	$5,500,771	15
Integrated Flight Systems	$11,321,497	46
Integrated System Research Project (ISRP)	$2,049,446	6
Unmanned Aircraft Systems	$5,980,928	18
Grand Total	**$127,262,562**	**417**

For inquiries:

(301) 937-0888

ARC-SBIR-Outreach@mail.nasa.gov

NASA Ames Research Center, M/S 202A-203
Moffett Field, CA 94035

www.sbir.nasa.gov

SBIR · STTR
America's Seed Fund™
POWERED BY NASA